Assessment of Hydropower Alternatives

Blackwater Dam Hydropower Study Webster, N.H.

JULY 1986

US Army Corps of Engineers
New England Division

EXECUTIVE SUMMARY

This report presents the results of a alternative assessment study on the addition of a hydropower facility to the existing Corps of Engineers Blackwater Flood Control Dam in Webster, New Hampshire.

The Blackwater Dam hydropower study investigated five plans for hydropower development. Each of the five plans was found to have a benefit-to-cost ratio above unity. The selected plan consists of a powerhouse located 1200 feet downstream connected to the dam by a 7-foot diameter steel penstock. The project powerhouse would consist of one standard tube unit with an installed capacity of 1700 kilowatts (Kw). The project would generate 4,067,000 Kilowatt-hours (kWh) annually at a total investment cost of $5,071,000 with a benefit-to-cost ratio of 1.66 to 1.0. Implementation of this plan would require the creation of a 28-foot deep permanent pool at Elevation 543 feet National Geodetic Vertical Datum (NGVD).

Using current Water Resources Council "Principles and Guidelines" criteria, the addition of a hydropower facility at Blackwater Dam has been found to be economically justified. The current administration policy on hydropower is to encourage non-Federal development, where feasible, unless non-Federal development is considered impractical. The development of the hydropower potential at Blackwater Dam could be pursued under the Federal Energy Regulatory Commission (FERC) procedures, consistent with current guidelines. It is the recommendatin of this report that no further study be undertaken at Blackwater Dam at this time. If non-Federal development is found to be impractical as some future time, then the completion of the feasibility study may be warranted.

Funding constraints did not permit the completion of a feasibility report as defined in the Corps' "Principles and Guidelines." These funding constraints permitted only baseline studies of archaeological, environmental, water quality, recreational, social and cultural conditions in the study area. Design and cost estimates proposed for this report are of feasibility level of detail. Each of the alternative hydropower developments investigated was compatible with the authorized purpose of this Federal project.

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I. INTRODUCTION

STUDY AUTHORITY

This is a report on the addition of a hydroelectric generating facility to the Corps of Engineers flood control project at Blackwater Dam in Webster, New Hampshire on the Blackwater River. Authority for this study is contained in Section 216 of Public Law 91-611 (the River and Harbor Act of 1970).

Under Section 216, the Secretary of the Army, acting through the Chief of Engineers, is authorized to review the operation of completed projects constructed by the Corps of Engineers in the interest of navigation, flood control, water supply, and related purposes, when found advisable due to significantly changed physical or economic conditions, and to report thereon to Congress with recommendations on the advisability of modifying the structures or their operation, and to improve the quality of the environment in the overall public interest.

STUDY PURPOSE AND SCOPE

The principal reason for this investigation is to determine whether an economically feasible hydropower development could be undertaken at the Corps' flood control project, Blackwater Dam. This document summarizes the results of the Corps' investigations from the reconnaissance stage to the present. In 1985, the Department of the Army published guidelines outlining the Federal Government's policy regarding hydropower. The guidelines stated that the Administration recognized the importance of hydropower to the Nation's economy, but felt that non-Federal interests should be encouraged to develop its potential, whenever possible. In keeping with this policy, limited funding was provided to complete the plan formulation portion of the investigation. Sufficient funding was not provided to complete the feasibility investigation consistent with the Corps of Engineers' "Principles and Guidelines." These funding constraints permitted only baseline studies of archaeological, environmental, recreational, social, and cultural conditions in the study area. Each of the alternative hydropower developments investigated was compatible with the authorized purpose of this Federal project.

STUDY OBJECTIVE

This report provides an indication of the potential for hydropower development at Blackwater Dam. This report defines the problems and opportunities of developing hydropower and identifies potential plans of development. The plans are formulated and assessed for social, cultural, environmental, and economic impacts. This investigation is conducted consistent with the "Principles and Guidelines" as amended by the President's Cabinet Council on Water Resources and Environment.

The Federal objective of water and related land resources project planning is to contribute to national economic development (NED) consistent with protecting the Nation's environment. Hydropower projects contribute to the national economic development. However, most hydropower projects can be planned, constructed, and operated by non-Federal interests without Federal assistance. The Federal interest is protected by the Federal Energy Regulatory Commission (FERC) procedures. Accordingly, in most instances, development must proceed under FERC procedures.

Recommendations for continued Federal study would be appropriate only if the proposed facilities would be impractical for non-Federal development or if the FERC procedures could not result in the optimum development of the resources as defined by "Principles and Guidelines." Non-Federal development of a hydropower potential at an existing or proposed Corps project is considered impractical if physical, legal, competing use, institutional, environmental, or economic reasons prevent non-Federal development or operation in as productive a manner (i.e., produce less NED net benefits generated by the overall project) as development by the Federal Government.

OTHER STUDIES

In 1939, prior to the construction of the Blackwater Dam, the Corps of Engineers undertook a brief study of the hydropower potential of the site on the Blackwater River. At that time, it was found that a peaking project having an installed capacity of 10,000 Kw could be economically developed if a larger dam and penstock were built and a larger conservation pool was maintained to provide storage for hydropower generation. An economic analysis was done for the project and a benefit-to-cost ratio slightly above unity was determined. Under provisions of the Flood Control Act of 1936, after consultation with the Federal Energy Regulatory Commission (at that time known as the Federal Power Commission), the Corps added minimum features to the dam (a 16-foot penstock intake) so as not to preclude the addition of hydropower at some future time, if a sufficient need for power existed. In 1954, as part of the New York - New England Interagency Committee resource study, a plan of development similar to the Corps' 1939 alternative was considered.

In 1981, the Corps completed a reconnaissance investigation of the hydropower potential at Blackwater Dam. This report found that a 600 Kilowatt installation with one unit was the most economically feasible project and recommended continued Federal investigation. Due to the limited scope of this study, no additional work was undertaken with regard to the alternatives developed in 1939 and 1954.

Preliminary permits have been issued by the Federal Energy Regulatory Commission (FERC) to various developers from early 1981 to the present. The last permit holder, Hydroelectric Development Incorporated, of Denver, Colorado, surrendered its permit on July 1, 1985. After the last permit was surrendered, there were three potential developers with applications under review by FERC. A preliminary permit was issued to Blackwater Dam Associates of Manti, Utah on May 28, 1986.

II. EXISTING CONDITIONS

PHYSICAL SETTING

The Blackwater Dam is a flood control project owned and operated by the U.S. Army Corps of Engineers. Located on the Blackwater River, about 8.6 miles above its confluence with the Contoocook River, the dam and reservoir lie within the corporate boundaries of Webster and Salisbury, in Merrimack County, New Hampshire. A general plan and vicinity map are shown on Plate 1.

The major physical components of the project are an earth dam, two earth dikes, and a concrete spillway and outlet works. Pertinent data for Blackwater Dam are summarized on Table 1.

The spillway consists of a concrete gravity-type ogee section that extends from the left abutment 240 feet across the river at Elevation 566 feet above the National Geodetic Vertical Datum (NGVD). A 16-foot diameter penstock intake was incorporated into the dam to allow for future hydropower additions.

The outlet works, located in the concrete spillway section, consist of three gated outlets, each 3'-6" wide x 5'-3" high, and one ungated outlet 3'-6" wide, 6'-6" high, with inverts at Elevation 515 feet NGVD. The ungated outlet is plugged. A general plan and elevation of the dam is shown on Plate 2.

The storage capacity of Blackwater Dam totals 46,000 acre-feet when filled to spillway crest. This is equivalent to 6.74 inches of runoff from the 128 square mile drainage area and would create a pool covering 3,280 acres.

Climate

The Blackwater River watershed has an average annual temperature of approximately 43°F with daily temperatures ranging seasonally from infrequent highs of over 100°F to occasional lows below -30°F. Average annual precipitation over the watershed is approximately 44 inches uniformly distributed throughout the year. During the winter months, much of the precipitation is in the form of snow, with an average annual snowfall in the project area between 80 and 90 inches. Water content in the snow cover varies from 5 to 7 inches, usually reaching a maximum about the middle of March.

TABLE 1
PERTINENT DATA - BLACKWATER DAM

Location	Blackwater River, Webster and Salisbury, Merrimack County, New Hampshire
Drainage Area	128 square miles
Storage Use	Flood Control

Reservoir Storage — Capacity

	Stage (ft, NGVD)	Area (acres)	Acre-Feet	Inches of Drainage Area
Inlet Elevation	515	0	0	0
Spillway Crest	566	3,280	46,000	6.74
Maximum Surcharge	579	4,030	47,400 (net)	6.94 (net)

Embankment Features

Type	Rolled earth fill
Length (feet)	1,150
Top Width (feet)	38.8
Top Elevation (feet, NGVD)	584
Height (feet)	75

Spillway

Location	Left abutment
Type	Gravity type, ogee section
Crest Length (feet)	240
Crest Elevation (feet, NGVD)	566

Outlet Works

Type	4 rectangular conduits (3 gated, 1 plugged)
Conduit Inside Dimensions (feet)	3.5 x 5.25 and one 3.5 x 6.5 (plugged)
Conduit Length (feet)	65
Service Gate Type	Three hydraulic gates
Service Gate Size (feet)	Three 3.5 x 5.25
Penstock Intake Diameter (feet)	16
Downstream Channel Capacity (cfs)	2,300
Maximum Discharge Capacity (Spillway Crest Elevation)	2,800 cfs
Stilling Basin	None

Lands	3,580 acres have been purchased in fee (to Elev. 566)

Watershed

The Blackwater River watershed is a subwatershed within the Merrimack River basin. The Blackwater River originates at the outflow of Pleasant Lake in New London, New Hampshire, and flows southeasterly, for a distance of 30 miles between Ragged Mountain and Mount Kearsarge, through the Blackwater Dam to its confluence with the Contoocook River. The Blackwater River has a drainage area of 136 square miles compared to the Merrimack River basin's total drainage area of 5,015 square miles. A watershed map is shown on Plate 3.

Within the flowage easement of the reservoir, the Blackwater River meanders through a valley bottom that is relatively flat (elevation 515 feet NGVD). This condition extends for only a short distance from the banks of the river before gentle slopes take over and extend to the boundaries of the Blackwater Flood Control Reservoir. Portions of the valley bottom and gentler slopes are cleared and used for pasturage under lease. Otherwise, the valley and slopes are heavily wooded. The river usually flows freely through the dam in a relatively natural state. However, during times of high runoff, the area behind the dam becomes a large reservoir holding back floodwaters.

Streamflow

A U.S. Geological Survey gaging station located downstream of Blackwater Dam has recorded river discharges since 1934. The average flow at Blackwater Dam is about 213 cfs. The maximum annual runoff was 34 inches in 1973 and the minimum annual runoff was 9 inches in 1965. Table 2 lists average monthly recorded flows over the past 45 years. A flow duration curve based on daily flow data for the period of record (1928-1984) is shown on Plate 4.

Reservoir Storage

Blackwater Dam contains reservoir storage for flood control only. The storage capacity totals 46,000 acre-feet when filled to spillway crest (Elevation 566 NGVD). This is equivalent to 6.74 inches of runoff from the 128-square mile drainage area, and would create a pool covering 3,280 acres. An area-capacity table for Blackwater Dam is shown on Table 3.

TABLE 2

Average Monthly Flows (45 Years Through 1979)
Blackwater River in Webster, New Hampshire
(Drainage Area = 128 Square Miles)

	Average Flow		Percent of Annual	Maximum Monthly		Minimum Monthly	
Month	cfs	inches	Runoff	cfs	inches	cfs	inches
January	164	1.47	6.5	455	4.09	44	0.39
February	159	1.28	5.7	484	3.91	42	0.34
March	350	3.13	13.9	1,394	12.45	50	0.45
April	698	6.04	26.8	1,249	10.80	256	2.21
May	368	3.28	14.6	746	6.67	106	0.95
June	173	1.50	6.7	380	3.29	45	0.39
July	84	0.75	3.3	436	3.89	19	0.17
August	56	0.50	2.2	192	1.72	10	0.09
September	69	0.61	2.7	710	6.14	11	0.10
October	88	0.78	3.5	293	2.62	31	0.17
November	165	1.39	6.2	462	4.00	38	0.33
December	198	1.77	7.9	557	4.98	50	0.45
ANNUAL	213	22.54		322	34.02	84	8.84

TABLE 3
BLACKWATER DAM AND RESERVOIR
AREA-CAPACITY TABLE
(Drainage Area = 128 Square Miles)

Pool Elevation (msl)	Area (acres)	Capacity Acre-Feet	Capacity Inches	Pool Elevation (msl)	Area (arces)	Capacity Acre-Feet	Capacity Inches
515		0					
516		10	.00	546	905	6,770	.99
517		20	.00	547	1,000	7,640	1.12
518		35	.01	548	1,095	8,640	1.27
519		55	.01	549	1,200	9,800	1.44
520	1	80	.01	550	1,310	11,150	1.63
521	2	110	.02	551	1,420	12,600	1.85
522	3	150	.02	552	1,530	14,00	2.05
523	4	200	.03	553	1,650	15,550	2.28
524	5	260	.04	554	1,770	17,300	2.53
525	8	335	.05	555	1,890	19,200	2.81
526	10	425	.07	556	2,020	21,200	3.11
527	13	530	.08	557	2,160	23,200	3.40
528	16	645	.09	558	2,300	25,400	3.72
529	20	770	.11	559	2,440	27,800	4.07
530	26	900	.13	560	2,580	30,300	4.44
531	34	1,040	.15	561	2,720	33,000	4.84
532	46	1,200	.18	562	2,860	35,500	5.20
533	63	1,390	.20	563	3,000	38,200	5.60
534	95	1,600	.23	564	3,100	40,600	5.95
535	135	1,840	.27	565	3,200	43,200	6.31
536	187	2,100	.31	566*	3,280	46,000	6.74
537	243	2,380	.35	567	3,360	49,000	7.18
538	300	2,680	.39	568	3,430	52,100	7.63
538	360	3,000	.44	569	3,490	55,400	8.12
540	420	3,340	.49	570	3,550	58,800	8.61
541	490	3,720	.55				
542	565	4,180	.61				
543	645	4,720	.69				
544	725	5,340	.78				
545	815	6,020	.88				

* Spillway Crest

ENVIRONMENTAL SETTING

Water Quality

The Blackwater River is deep and slow moving with an average width of 100 feet as it meanders approximately 14 miles through the project area. The waters of the Blackwater River and its tributaries are assigned the Class A objective classification by the State of New Hampshire. Under New Hampshire standards, Class A waters are of uniformly excellent quality and are "potentially acceptable for water supply uses after disinfection" as well as all other less stringent uses. There can be no discharge of sewage, wastes or other polluting substances into the waters. Class A waters do not have less than 6 ppm of dissolved oxygen (DO), or less than 75 percent of DO saturation. There are no pH or color limits except as they naturally occur. Turbidity levels must be not more than 5 standard units while coliform levels cannot be more than 50 coliforms per 100 ml unless naturally occurring.

Information obtained from the New Hamsphire Water Supply and Pollution Control Commission (NHWSPCC) has indicated that the actual water quality condition in the area of the dam is Class B. In the absence of known point source discharges upstream from the dam, it is assumed that the river is degraded to this condition by natural factors and nonpoint sources. Under New Hampshire standards, Class B waters are acceptable for recreation, fish habitat and fishing, and for water supply only after adequate treatment. Parameters are somewhat similar to the Class A designation except for those involving coliform bacteria (not more than 240 coliforms/100 ml) and turbidity (not to exceed 10 standard units for cold water fisheries and 25 standard units in warm water fisheries). Other parameter limits are also relaxed (such as pH, oil and grease, odors, sludge deposits) but cannot be distinguished from Class A standards except in a qualitative way.

Data have been collected by the Corps since 1970 at three different sampling areas: upstream from the project on Blackwater River, on a small tributary of the Blackwater, Mill Brook, and just downstream from the dam. Analysis of the data indicates that although a majority of the classification criteria are met, violations have occurred from the parameters of dissolved oxygen and total coliform.

The dissolved oxygen saturation limits are violated on about 8 percent of the sampling dates on the Blackwater River upstream from the project and about 3 percent of the sampling dates downstream from the project. Very few data have been collected on total coliform, but of those collected, results show that violations have occurred on about 60 percent of the sampling dates.

Data collected on metals show very few problems with the exception of iron and manganese. Data collected for iron indicate that limits on iron for drinking water were violated on 40 to 50 percent of the sampling dates, while those limits placed on manganese were violated in about 5 percent of the samples.

Nutrient loading generally has been low, although a few total phosphorus data points have exceeded the threshold levels for algae blooms (greater than 0.1 mg/l phosphorus). pH levels for the project normally range between 6.4 and 7.0 while data collected on hardness indicate that the water is very soft, as is typical of most New England streams.

Aquatic Ecosystem

The Blackwater River, classified as one of the best trout streams in the southern portion of the State, is stocked annually by the New Hampshire Fish and Game Department with brook trout (Sglveninus fontinalis), brown trout (Sglmo trutla) and rainbow trout (Sglmo ggirdner). There is high fishing pressure on the river with an estimated 50 percent return on released fish. Other species found in the river include chain pickerel (Esox niger), brown bullhead (Ictalurus nebulosus), white perch (Morone americana), smallmouth bass (Micropterus dolomieui), pumpkinseed sunfish (Lepomis gibbosus) and bluegill (Lepomis macrochirus).

Terrestrial Ecosystem

Most of the land of Blackwater Dam and Reservoir is in forest cover. Predominant forest species are white pine (Pinus strobus) and hemlock (Tsuga canadensis). Associated hardwoods include sugar maple (Acer saccharum), gray birch (Betula populifolia), yellow birch (Betula lutea), paper birch (Betula papyrifera), and red oak (Quercus rubra). Along the river quaking aspen (Populus tremuloides), red alder (Alnus rubra) and willow (Salix, sp) are dominant.

The project serves as habitat for a variety of resident and migrating wildlife. White-tailed deer (Odocoileus verginianus) is the only "big game" species occurring commonly. Occasionally a black bear (Ursus americanus) is found in the area. Other resident species include the red fox (Vulpes fulva), snowshoe hare (Lepus americanus), gray squirrel (Sciurus carolinensis), raccoon (Procyon lotor), muskrat (Ondatra zibethica), mink (Mustela vison), beaver (Castor canadensis), ruffed grouse (Bonasa umbellus), woodcock (Philohela minor) and ringnecked pheasant (Phasianus colchicus). Waterfowl do breed in the reservoir area. Black duck (Anas rubripes), wood duck (Aix sponsa), hooded merganser (Lophodytes cucullatus) and mallard (Anas platyrhynchos) are the main species present during the nesting season. In general, there is moderate to heavy hunting pressure on the project lands. Trapping is primarily for muskrat, mink and beaver.

Threatened and Endangered Species

Currently there are no Federally-listed threatened or endangered species known to occur in the project area (U.S. Fish and Wildlife Service, personal communication).

RECREATION RESOURCES

The present lack of a permanent pool at Blackwater Dam and local oppostion to any intensive development on project lands have limited the types of activities available. Principal recreational activities include sightseeing, swimming, snowmobiling, hunting, picnicking and fishing. Present recreational facilities consist of an overlook and parking area at the dam, 20 miles of snowmobile trails and numerous access points for hunters and fishermen. There are no swimming facilities, however considerable informal use takes place in local swimming holes in the river. Visitation to the project in 1985 was about 29,000 people.

Recreation facilities are also available at several municipal, state and private recreation areas in the vicinity. The town of Webster operates a swimming beach at nearby Pillsbury Pond. Hunting and fishing opportunities are available at the 983-acre Knights Meadow Marsh, in Webster, at the Kearsarge Mountain State Forest and Nursery State Forest, in Salisbury, and the Harriman-Chandler State Forest and Kearsarge Mountain State Forest in Warner, New Hampshire. Picnicking is available at Rollins State Park and Kearsarge Mountain State Forest in Warner, and at several municipal and private facilities in the vicinity.

HISTORICAL AND ARCHAEOLOGICAL RESOURCES

No prehistoric sites have been reported within the Blackwater Dam project area. This is probably due to absence of reports rather than sites, as environmental characteristics of the area indicate a high potential for presence of such resources. The project area includes extensive well drained floodplain terraces suitable for prehistoric occupation, while the river and adjacent wetlands could have provided attractive aquatic resources. Further, the nearby Merrimack River was an area of intensive and extensive prehistoric occupation, as well as a major travel route at the time of European contact. The nearby Blackwater River undoubtedly experienced some of this activity.

Historic occupation of the project area began during the 1750's and intensified following the French & Indian War. The town of Boscawen was incorporated in 1760 and Salisbury in 1768. Webster, long a part of Boscawen, was incorporated in 1860. Throughout the historic period, most residents of the project area were farmers, though a number of small mills were built on the river at the present dam location and slightly north of it. Structures of the 19th century or earlier, removed prior to dam construction in 1941 and within the project area of hydropower alternatives, include six dwellings, two mills, three bridges, the Webster town hall, and a cemetery (all burials relocated). Archaeological evidence of all of the above sites exist within the project area.

Additionally, while the series of mills (Known as Swett's Mills) were obliterated by dam construction in 1941, most of the 19th century structures of the adjacent village still exist downstream. These include a church, grange hall and part of a store. Sites of several other structures, including a blacksmith shop are also present within the village.

SOCIOECONOMIC SETTING

Blackwater Dam and reservoir is located on the Blackwater River in the towns of Webster and Salisbury, New Hampshire. The structure is located in the town of Webster, however, the majority of the reservoir area is in the town of Salisbury. The two towns are located in Merrimack County, northwest of the city of Concord.

The town of Webster has a total land area of approximately 18,715 acres or 29.2 square miles with a density of 37.4 persons per square mile in 1980. In the early 1970's, forest land accounted for close to 84.3 percent of the total acres. Agriculture constitutes the second largest use of land. Of the 1.2 percent which is developed, the majority was residential. Between 1950 and 1975, Webster showed a decrease in agriculture while development and forest land usage increased. In the early 1950's, Webster did not contain any independent residential development; all structures were farm houses or farm related structures. However, by the early 1970's independent residential areas had been constructed contributing to the development of Webster.

The town of Salisbury's total land area is approximately 24,475 acres or 38.2 square miles with a density of 20.4 persons per square mile in 1980. Like Webster, forest land constitutes the majority of land usage, about 87.9 percent; and agriculture accounts for the second largest use. Between 1950 and 1975, Salisbury showed a decrease in agriculture while idle land increased by almost 219 percent. This idle land is expected to be used for residential development in the future.

Population

From 1930 to 1960, the population in Webster showed a growth rate of 26.9 percent, which was slightly higher than that of both the county and state. By 1980, with an increase of 138.9 percent since 1930, Webster has grown by a factor of three times that of Merrimack County and the State of New Hampshire. This increase in residents between 1960 and 1980 can be attributed to the residential development of the Pillsbury Lake Area during the late 1960's. In addition, Webster has become a bedroom community. More people seeking to leave city living find Webster to be a convenient location. While rural residential in nature with little industry of its own, the town borders a major city and the State Capital, Concord, on it southeast border.

Salisbury also showed a growth rate slightly higher than both the county and state. Between 1930 and 1980, Salisbury's population increased by 123.1 percent. However, Salisbury's growth rate was lower than Webster's. Salisbury is mainly agricultural and has recently became more residential. The town is slowly evolving into a bedroom community for people who wish to escape city living but wish to remain within proximity of the major city, Concord. In fact, a large number of the non-farming residents of both Salisbury and Webster are employed in Concord. Yet, planners are presently attempting to limit growth through zoning restrictions on development. Population figures for the towns, county, and state are presented in Table 4.

TABLE 4
Population
Salisbury, Webster and Merrimack County, New Hampshire

	Salisbury	% Change	Webster	% Change	Merrimack County	% Change	N.H.	% Change
1930	350		360		56152		465293	
1940	368	5.1	351	-2.5	60710	8.1	491524	5.6
1950	423	14.9	386	10.0	63022	3.8	533242	8.5
1960	415	-2.0	457	18.4	67785	7.6	606291	13.7
1970	589	41.9	680	48.8	80925	19.4	737681	21.7
1980	781	32.6	1092	60.6	98038	21.2		24.5

Economy

The town of Webster contains two manufacturing businesses - Mellon Company and Yankee Pinecraft Furniture, and two commercial establishments. Salisbury has no industrial development and only one commercial establishment. Therefore, many nonfarming residents of these towns have jobs situated elsewhere in Merrimack County; a large number of these residents are employed in Concord. Statistics on industry for Merrimack County showed that of those employed in 1979, the largest number, about 22.6 percent, were found in manufacturing. Manufacturing was followed by the government as the second largest employer. About 77.3 percent of those employed by the government worked for the State and local governments. Employment in services and trade were also of importance for the county.

RESERVOIR REGULATION

The principal purpose of the Blackwater Dam and Reservoir is flood control. Blackwater Dam is operated in conjunction with Hopkinton-Everett and Franklin Falls Reservoirs to protect the downstream communities on the Blackwater and Contoocook Rivers. The project also provides protection for the major industrial, commercial and residential centers along the Merrimack River such as Concord, Manchester, Nashua, Lowell, Lawrence and Haverhill. The coordination of the various reservoirs is covered in the Merrimack River Basin Master Manual.

The three gates at Blackwater Dam are normally maintained at an opening of three feet above the gate sill, which will automatically throttle releases during an unexpected river rise. During minor rises, gate changes will not normally be made unless instructions are issued by the Corps Reservoir Control Center, located in Waltham, Massachusetts.

During normal non-flood periods, the reservoir outflow equals inflow. During flood periods, runoff is temporarily stored in the reservoir and released as soon as the Contoocook and Merrimack Rivers' flood levels recede. If it becomes necessary to completely restrict outflows in a moderate or major flood event, a minimum flow of approximately 20-25 cfs would be released in order to sustain downstream fish life. The Corps recognizes that flood runoff from the downstream areas will significantly increase the river flows above this minimum discharge rate.

Following the downstream recession of flood stages on the Merrimack River, stored floodwaters are released as rapidly as possible, consistent with amounts of reservoir storages utilized, downstream flows, channel capacities, weather forecasts and travel time. The maximum nondamaging channel capacity downstream of the dam is 2,300 cfs. Releases of this magnitude are not usually made unless considerable flood control storage is utilized. When releases exceed 2,000 cfs, downstream conditions are periodically inspected. Increases in discharge should not exceed 300 cfs per hour until 1,800 cfs is reached, then 100 cfs increments until nondamaging channel capacity is attained.

It is the policy of the Corps of Engineers to cooperate with downstream water users and other interested parties or agencies. The Project Manager may be requested to deviate from normal regulations for short periods. Whenever such a request is received, the manager shall ascertain the validity of the request and obtain assurances from the downstream water users that they are agreeable to the modified operation.

III. PROBLEM IDENTIFICATION AND OPPORTUNITIES

The preservation of a dependable, inexpensive supply of electricity has long been recognized as an important commodity to the people of New England and to the economy of the region. The Public Service of New Hampshire (PSNH) is the primary electric utility serving the state of New Hampshire. The PSNH utilizes coal, fossil fuel, hydropower, nuclear and electricity purchased from small energy producers to maintain electrical service to the state. The company is also a part owner with other New England electric utilities of four nuclear generating companies. The PSNH is a member of the New England Power Pool (NEPOOL), which was created in 1971 by the majority of New England's electrical utilities to enhance the performance of efficiency of their numerous generating facilities. The NEPOOL utilizes an extensive computer and communications network to coordinate the production of electricity throughout New England to increase the overall efficiency of it's systems and minimize the required reserve capacity. This optimization of the overall generation network results in a low cost of energy production.

The electrical properties of the PSNH form, a single integrated system including transmission facilities, which are part of the New England-wide transmission grid. The company has 1,183 MW of its own generating capacity, 98 MW from its participation in the four nuclear generating co-ownerships, and various contracts for purchased energy. At the end of 1984, PSNH produced approximately 45 percent of its energy from oil, 39 percent from coal, 9 percent from nuclear and 7 percent from hydropower and contract purchases. The PSNH is presently constructing the Seabrook Nuclear Power Plant. The project will have a total capacity of 1,150 MW of which 409.05 belongs to PSNH. The project is scheduled to be completed in October of 1986, however, the completion date has been deferred from time to time in the past, and additional delays may occur in the future. When the Seabrook plant comes on-line, the PSNH's percent of nuclear generation will increase to approximately 40 percent, reducing their coal generation to 34 percent and oil generation to 18 percent. A portion of the oil generation reduction will be due to PSNH's ongoing program of converting existing oil-fired plants to coal-generating plants.

The demand for electrical energy varies significantly depending upon the time of year and the time of day. The amount of electricity demanded by consumers during the peak period of the day may drastically exceed the demand during the low period of the day. Because consumers' habits tend to be similar, however, this rise and fall in demand is reasonably predictable. The NEPOOL utilizes numerous types of generating facilities to meet these diversified demands on the system. The selection of the type of plant is based on the type of load the plant will serve and the availability, cost and special characteristics of each fuel. Certain plants, such as nuclear, operate continuously to meet the constant, base load, portion of the system demand. A second type of plant produces the energy required to provide the intermediate level demands resulting from the greater daytime energy use. A third type of plant, called a peaking plant, is used to handle the rapid upsurges in demand that occur during the peak times of each day.

A study by the U.S. Department of Energy projected that the demand for electricity in New England will grow at a rate of 2.1 percent per year for the period 1985-1995. The constant growth rate for electrical energy in New Hampshire indicates that the Federal forecasts may be conservative for the region. New Hamsphire experienced a 3.6 percent increase in 1983, a 6.1 percent increase in 1984 and a 3.4 percent increase in the first three quarters of 1985. The NEPOOL projects that New England will require additional generating capacity by 1994 even with the addition of the Seabrook nuclear power project in New Hampshire, Milstone III in Connecticut, and the contracted power purchases from Hydro-Quebec.

Nonstructural measures associated with enhancing public awareness of the need to conserve energy have been implemented in New Hampshire with some success. Studies on the impacts of conservation indicate that there is an acceptable comfort and convenience level beyond which consumers seem unwilling to go. Until conservation can supply both comfort and convenience in a far more cost effective way than it does today, no additional contributions will be made. Future long-term achievements may be made as technology improves, however, these developments will not happen rapidly enough to offset the increase in generation requirements.

Small power producers and cogeneration production has been offered as a possible answer to the growing energy demand. The PSNH presently has 87 contracts to purchase power from small energy producers. These producers use or plan to use wind, wood, methane gas, natural gas, photovoltaics and hydropower. Three-fourths of all present agreements cover hydropower projects. Even if all these sources come on-line, they will produce only 6 percent of the projected peak demand.

The New England electric utilities, including the PSNH, make greater use of fuel oil for the generation of power than utilities in any other region of the county. The PSNH has predicted that their dependency on oil generated energy will be reduced from 45 percent to 18 percent by the generation of Seabrook, however, NEPOOL forecasts that overall, New England will require oil-generation to provide approximately 43 percent of their total energy demand. Much of the fuel oil supplies for New England utilities are derived from foreign sources, which are subject to unstable prices and supplies. This unpredictability of the oil market has encouraged the expanded use of alternative energy sources. In 1983, hydropower generation provided 6 percent of the total demand. The additional development of available alternative energy resources including hydropower would not drastically impact on the overall future power needs. The development of these resources can, however, reduce the amount of oil-generated energy.

Development of the hydropower potential at the Blackwater Dam flood control project provides an opportunity to develop a safe, dependable, environmentally attractive, relatively inexpensive source of electricity within the constraints of the existing reservoir area and existing project purposes. The savings in cost of power production could be realized by a large number of households. The conservation of fossil fuel can be measured in thousands of barrels of oil annually. This project is an opportunity to contribute to solving the continuing problem of the New England's dependence on oil-generated electricity.

FUTURE CONDITIONS WITHOUT THE PROJECT

No significant changes in the physical, environmental, cultural, social or economic conditions are envisioned in the study area. No significant changes in the reservoir regulation are expected. However, the projected gradual increase in population could result in subtle changes to the environment and water quality of the Blackwater River.

The forecast of the future energy demands in New Hampshire are dependent upon the economic growth and population variations of the region. The PSNH has predicted that with the addition of the Seabrook Nuclear Facility, 18 percent of their annual generation will remain oil dependent. With the continued growth of energy demands combined with the NEPOOL forecasts for the need of new generating capability, it can be assumed that the percentage of oil-generated energy will increase over the next several decades. Without the development of alternative energy resources by the PSNH, the State of New Hampshire's dependency on oil-fired generation will continue to increase.

PLANNING CONSTRAINTS

Planning contraints are conditions imposed on the planning process that limit the range of feasible alternatives available to the planner. These constraints may consist of legal, social and environmental factors of such importance that violating them would compromise the entire planning effort.

Blackwater Dam is the single purpose flood control project operated to reduce floods on the Blackwater and Contoocook River and in concert with other reservoirs to reduce floods on the main stem of the Merrimack River. Any hydropower additions to this project must not interfere with the dam's designed flood control operation. A preliminary investigation was undertaken (Appendix A) to determine if a portion of the existing flood control storage could be reallocated for hydropower generation. The study concluded that encroachment of the existing storage to Elevation 543 feet NGVD would not significantly impact the project's flood control operation. Further investigation may be required to fully evaluate the impact of storage reallocation to the dam's flood control function. Development of a permanent pool to Elevation 543 feet NGVD represents a loss of 4,700 acre-feet equivalent to 10 percent of the project's reservoir's total capacity.

In the design of any hydroelectric generating facility, measures must be taken to the extent possible, to minimize environmental and social disruptions and still optimize the power potential of the site. Future studies would include detailed impact assessments of any archaeological, environmental and water quality impacts of the proposed alternatives.

It is the policy of the Federal Government to encourage non-Federal interests to develop the hydropower potential at Federally owned projects where feasible and compatible to authorized project purposes. Federal hydropower development would only be pursued where non-Federal activity is considered impractical. In accordance with this policy, it is the practice of the Corps of Engineers to suspend all hydropower study activities at Corps-owned projects if a Federal Energy Regulatory Commission (FERC) license is issued to a non-Federal entity for that same project or if the Federal development of energy at a Corps project would adversely impact on a planned or existing non-Federal hydropower project. In keeping with this practice, the Corps of Engineers, New England Division, would forego future hydropower studies at Blackwater Dam if the project would impact on the planned hydropower project by a private interest.

Minimum Flow Requirements

The steep drop in the Blackwater River below the Corps' flood control project offers the potential to increase the generating head of the project by locating the powerhouse at a point downstream of the dam. The construction of this type of installation would bypass a portion of the river channel during hydropower operations. The U.S Fish and Wildlife Service (FWS), in a planning aid letter to the Corps of Engineers recommended that an aquatic base flow of 44 cfs be maintained whenever stream flow permits. This value represents the historic median August flow for New England which has been determined to be 0.5 cfs per square mile of drainage area. The 7 day, 10 percent probability flow, the standard water quality minimum flow requirement, was determined to be 15 cfs. This value is considerably below the FWS requested aquatic base flow. The Corps of Engineers has a policy of maintaining a 20-25 cfs minimum base flow at Blackwater Dam during flood control operations.

Funding limitations did not permit an analysis of the Blackwater River to determine an appropriate minimum flow. For the purpose of this report a 20 cfs minimum flow was assumed. Further investigation would be required to determine the low flow requirements for a downstream hydropower project.

IV. PLAN FORMULATION

INTRODUCTION

The retrofitting of a hydropower installation to the existing Blackwater Dam is limited by the present design of the structure. Cost estimates were developed to determine the economic benefit of raising the top of dam and spillway elevations to permit a higher operating pool level. The analysis found that the prohibitive costs associated with this construction would not be offset by the revenue derived from the increased hydropower generation. Three installation schemes were developed which could be incorporated into the existing dam. The first would place submersible turbine/generator(s) within a concrete weir constructed upstream of the dam's outlet works. This option would be a run-of-river installation that would be limited by the flow conditions through the dam's outlet structure. The pool level for this option would be determined by the manufacturers' specifications for the selected hydropower unit and would be considerably below the maximum allowable pool elevation of 543 feet NGVD. The second and third installation schemes would consist of run-of-river installation utilizing the maximum permissible pool elevation without dam modifications. The second installation scheme would consist of a conventional downstream powerhouse located at the foot of the dam. The third installation scheme would consist of a powerhouse located downstream of the project, connected to the dam by a steel penstock. Earlier schemes involving storage and peaking operations were found to economically not justified in the preliminary screening investigation.

The streambed profile of the Blackwater River downstream of the Corps' flood control dam is characterized by reaches with moderate changes in elevation. This elevation differential provides an opportunity to increase the generation capability of a hydropower installation by locating the powerhouse at some point downstream of the dam's outlet. Prior investigations identified three potential powerhouse locations and penstock routes. The first alignment would consist of a 1,150 foot long penstock located along the riverbed connecting to a powerhouse just downstream of the Route 127 bridge. The second alignment would be a 2,100 foot long penstock with an overland route past the town of Webster's Public School. The penstock would connect to a powerhouse located approximately 2,800 river feet from the dam. The third alignment would be a 10,000 foot long penstock with an overland route, which would connect to a powerhouse located at the Snyder Mills site on the Blackwater River. Preliminary screening investigation indicated that the 10,000 foot long penstock alternative would not be economically justified. Detailed cost estimates were prepared for the remaining two alignments to determine the optimum penstock route. The cost estimates were based on photogrammetric mapping procured for this study. The results of this investigation indicated that the 1,150 foot penstock adjacent to the river at the top of the right bank was the most economically attractive alternative. A copy of the photogrammetric mapping used for the penstock study is shown on Plate 5.

For each of the installation schemes a matrix of alternatives were developed to evaluate the available energy potential under various pool elevations, powerhouse locations and penstock routes. Each hydropower design configuration was analyzed using the Corps' HYDUR (Hydropower Analysis Using Streamflow Duration Procedures) computer program. The program used the flow duration curve computed at the dam along with cost information developed by the Corps of Engineers to size and cost projects at various intervals of percent flow exceedance. The program then selects an optimum project for each set of conditions on the basis of net tangible benefits. The economic evaluation performed by the computer program is based on generic information compiled for the purpose of developing preliminary cost estimates. The cost estimates developed by the program do not represent the anticipated cost of construction at the Blackwater Dam, however, it does establish a median condition with which to evaluate the economic potential of the various hydropower alternatives.

The optimum projects selected for each set of conditions were compared to determine the best design for each installation scheme. Designs and cost estimates were prepared for the selected alternatives. The first two alternatives would consist of a submersible turbine-generator(s) placed within a concrete weir upstream of two of the dam's outlet gates. The project would be operated at pool Elevation 530 feet NGVD. The third alternative would consist of a powerhouse constructed at the right downstream toe of the dam. The project would consist of a single unit operated as a run-of-river installation. The fourth and fifth alternatives would consist of a powerhouse constructed adjacent to the riverbank a few hundred feet downstream of the Route 127 bridge. The project would be connected to Blackwater Dam's plugged 16 foot penstock opening by a 1,150 foot steel penstock. The project would consist of two unequally sized units and would be operated as a run-of-river operation.

DESIGN CRITERIA

Hydraulic/hydrologic. The purpose of this investigation is to determine the feasibility of adding hydroelectric generating facilities to the Blackwater Dam project. In view of the limited scope of this effort and the inherent hydrologic and hydraulic constraints, it was decided that only run-of-river hydropower alternatives would be considered at this time. The different schemes investigated are intended to displace the output of a combined cycle oil-fired thermal facility. The schemes are designed to be operated as run-of-river projects, thereby minimizing fluctuations of the reservoir level during hydropower operations. Hydropower operations which utilize temporary storage to increase energy generation were not considered due to their possible conflict with the flood control operation.

The hydropower potential of a volume of water is a function of its weight and the vertical distance it can be lowered. The function of a water power facility is to transform this gravitational potential energy into mechanical energy, by turning a turbine, thence electrical energy via a generator. The rate of power generation, normally measured in kilowatts, is determined by the formula:

$$P = \frac{EHQ}{11.8}$$

where

P = Power of capacity in kilowatts
E = Combined turbine and generator efficiencies
Q = Rate of discharge in cubic feet per second
H = Net hydraulic head in feet

With today's highly efficient turbines and generators, an average combined efficiency of 80 percent can be reasonably assumed for a typical range of operating head and discharge conditions. The potential amount of energy generation over a period of time is normally measured in kilowatt-hours and is equal to the average capacity times the duration of generation.

The potential amount of water power of any stream is a function of the average streamflow and the average annual hydraulic head. Both the rate of discharge and the head are quantities which may fluctuate, therefore, it is the magnitude of these two quantities and their variability that determines the potential energy of a site and its dependability.

There are both head and flow limitations on the operating capability of hydraulic turbines. The upper and lower turbine flow limits are typically expressed as a function of the design discharge, i.e., the flow that will produce the maximum turbine output at the design head. The allowable operating range of a turbine is determined by the type of turbine and its characteristics. The operating limits of the selected turbine are plotted on the flow duration curve. The area under the curve inclosed by these limits establishes the theoretical average flow available to the turbine 100 percent of the time. This flow is converted into an average power output from the previously described power equation multiplied by 8,760 hours in a year, giving the average annual energy, in kilowatt-hours, which could be generated by a plant of the assumed capacity. The average annual energy is divided by the total generation potential to determine the percent time of operation, known as the plant factor.

The streamflow duration curves developed at Blackwater Dam were based on 58 years of streamflow records at a USGS gaging station on the Blackwater River located approximately 2 miles downstream of the dam. Design flows for the hydropower installations were established using the HYDUR computer program. Average annual energy values were calculated based on a run-of-river hydropower operation. Net heads for each of the alternatives was the elevation differential between the pool level at the dam and the tailwater at the installation discharge with allowances for operating head losses. A tailwater rating curve for the outlet gates was developed to determine the discharge capacity of the submersible hydropower installation.

Foundation Condition. No new subsurface investigations were performed for this study. The foundation conditions for the proposed powerhouse, penstocks and weir structures were inferred from the original explorations performed for the construction of Blackwater Dam. Alternatives 1 thru 3 involve the construction of permanent structures in the immediate vicinity of the dam's outlet works and spillway. Several borings located in this area were used to determine the rock profiles for these alternatives. Alternatives 4 and 5 involve the construction of a powerhouse located approximatley 1,150 feet downstream of the dam. The powerhouse will be connected to the dam by a steel penstock that will run along the right riverbank. Overburden along this alignment ranges from 0 to 5 feet thick, and consists primarily of sand and gravelly sand with cobbles.

Control of Water. During construction of the proposed concrete weir structure for the submersible installation (Alternatives 1 and 2), the site must be dewatered. The proposed diversion scheme involves the construction of a gravel fill cofferdam across the streambed to Elevation 523 feet NGVD. The cofferdam would be made impervious by placing an impervious membrane on its upstream slope. The slopes and crest of the cofferdam will be protected with an 18-inch layer of stone protection. Normal stream flows would be diverted through two 5-foot diameter corrugated metal pipes which would pass through the cofferdam and tie into two of the existing flood control conduits. One of the pipes would tie into the ungated outlet which was plugged in 1951, and the other will tie into the adjacent gated outlet.

Alternative 3 involves the construction of a powerhouse excavated into the streambed at the downstream toe of the dam. A 3-foot high sandbag cofferdam would be used to divert water around the construction site. Alternatives 4 and 5 involve the construction of a powerhouse on the right bank of the Blackwater River at some point just downstream of the dam. In order to dewater the construction site, a cofferdam constructed to an elevation above the streambed would be required. The cofferdam will tie into the existing streambank immediately upstream and downstream of the site. The height of the cofferdam would vary from 5 feet to 10 feet above the streambank depending on site conditions at the selected powerhouse location. The cofferdam would be constructed of random fill from the required excavations for the project with an impervious membrane and stone protection on the riverside slope.

Electrical Connection. The local utility in Webster, New Hampshire, Public Service of New Hampshire, has a 13.8 kv 3-phase aerial cable which runs along Route 127. For Alternatives 1 thru 3 , the interconnection to the utility distribution system will be made at the corner of Little Hill

Road and the entrance to the dam's control house. The connection to the system would be accomplished using a transformer located at the hydropower installation. The remaining alternatives' output voltage will be distributed to the utility without the use of a transformer. All required line protection and pole line interface equipment will be located within the switchyard and powerhouse structure. The electrical connection to the utility will be made at the corner of Little Hill Road and Route 127.

General Design. Detailed design and cost estimates were performed on the five alternatives which showed economic justification based on the initial screening procedure. Plans were developed using topographic mapping obtained prior to the original construction of the dam and on photogrammetric data generated in the area just downstream of the dam. This new topographic data was used to calculate accurate river profiles downstream of the dam, and in the selection and costing of the selected penstock route. Quantities were determined based on average sections and center line profiles using standard estimating procedures. Current unit prices for this area were utilized for bulk quantities including various fill material, general excavation, rock excavation, mass concrete and reinforced concrete. The selection and cost of the selected turbines and gate equipment was coordinated with equipment manufacturers. The designs and costs for the remaining components were determined using standardized cost information.

PROJECT DESCRIPTION

Alternative 1 would consist of a submersible turbine/generator located upstream of the dam within a new weir structure encompassing the two right-most outlet gates. The unit would be placed in a structure directly behind the dam's right outlet passage. A seperate weir would be constructed at the center outlet conduit. The height of the structure housing the unit would be at Elevation 533 NGVD, three feet above the weir pool elevation of 530 NGVD. This configuration would allow the unit to operate under a relatively constant flow and head. The submersible hydropower installation would utilize the head differential between the pool elevation and the tailwater elevation within the turbine structure. The unit would operate under a constant design flow with the remaining flows passed over the weir. Under these conditions, the tailwater elevation in the weir is dictated by the hydraulic capacity of the outlet entrance to discharge flows under open channel conditions and is independent of the operation of the hydropower units. This method of operation would not place the dam's outlet works under pressure and would negate the Corps of Engineer's requirement to insert a tunnel liner within the outlet works. A tailwater rating curve for this installation is shown on Plate 6.

The installation scheme developed for this alternative would consist of a single turbine/generator with an installed capacity of 56 Kw. The project would operate at pool Elevation 530 NGVD under a design head of 10 feet and would have a design flow of 98 cfs. The project would operate as a run-of-river installation, producing approximately 302,000 kWh annually, with a total investment cost of $563,000. It is estimated that the project would be completed within six months assuming advanced aquisition of the turbine and other fabricated items. For this investigation it was assumed that site access to the project during operation would be eliminated. This would result in the need to lower the pool level if major maintanance is required. Since the projects are designed to be unmanned, permanent site access was omitted. If access to the project was added, the increase in the construction cost would be approximately $40,000. A description of this alternative is shown on Plate 7.

A modification to the above described installation scheme was evaluated for a comparison of possible operation methods. Alternative 2 would consist of two submersible turbine/generators, with a total installed capacity of 112 Kw, housed in a concrete weir encompassing the center and right bank outlet passages. The weir would have a uniform elevation at 530 feet NGVD and would not have a center partition. The project would pass the operating flows through the turbines with the excess flows passing over the weir. The tailwater condition within the weir would be controlled by the capacity of the two outlet passages to discharge flows. The units would operate within the specified operating head range and would discontinue operating when the tailwater conditions within the weir reduce the net head below operating requirements. This alternative would produce a greater amount of energy while operating, but with a reduction in time of operation. The project would operate as a run-of-river installation, producing approximately 400,000 kWh annually, with a total investment cost of $799,000. Plate 8 shows pertinent features for this alternative.

Alternative 3 would consist of a single standard tube unit housed in a powerhouse located on the right bank immediately downstream of the dam. The far right outlet conduit would be lengthened and lined and a short penstock added to reach the proposed powerhouse. A hydraulically operated gate located at the downstream end of the extended conduit would be used to pressurize the system for power generation. During flood control operations, this gate would be opened and the existing upstream flood control gate used to regulate releases in accordance with current procedures. Access to the site after construction would be by crane and stairways from the existing parking area. A permanent pool would be maintained at Elevation 543 feet NGVD by the operation of the existing flood control gates. The project would have an installed capacity of 615 Kw under a 29 foot head with a design discharge of 305 cfs. The project would produce 1,892,000 kWh per year and would have a total investment cost of $2,672,000. It is estimated that the project would be completed within one year assuming advanced aquisition of the turbine and other fabricated items and initiating construction in the winter. A description of the alternative is shown on Plate 9.

Alternative 4 would consist of a powerhouse located on the right bank adjacent to the highway department and storage area just off Route 127.

The powerhouse would be connected to the dam's 16-foot diameter plugged penstock stub by a 1,150 foot long, 7-foot diameter steel penstock. The powerhouse would consist of one standard tube unit with an installed capacity of 1,700 Kw. The project would operate as a run-of-river installation under an effective head of 64 feet and a design discharge of 305 cfs. The project would produce approximatley 4,067,000 kWh of energy per year with a total investment cost of $5,071,000. It is estimated that this project could be constructed in a two-year time frame.

Alternative 5 would utilize the identical design scheme as Alternative 4, however, the 1,700 Kw installed capacity would consist of two unequally sized standard tube units. The smaller unit would have an installed capacity of 575 Kw with a design flow of 125 cfs. The larger unit would have an installed capacity of 1,125 Kw with a design flow of 245 cfs. The project would produce approximately 5,093,000 kWh per year and would have a total investment cost of $6,848,000. A description of Alternatives 4 and 5 is shown on Plate 10.

ROAD RELOCATIONS

The implementation of a permanent pool at Elevation 530 feet NGVD would not impact on any existing roads or access ways through the project impoundment area. Implementation of a permanent pool at Elevation 543 NGVD may impact a town road which passes through the dam's impoundment area. Interpolation of the topographic mapping in this area places a portion of this road in the vicinity of Elevation 545 feet NGVD. The road presently provides access to the Blackwater reservoir during normal project operation, however, during high pool stages the road is barricaded forcing traffic to detour around the project. Additional topographic surveys would be required to determine the exact impact to the road.

At the time the project was constructed the Government acquired all rights from the Town of Webster for the roads within the project impoundment area. This acquisition permits the Government to flow these areas to any elevation. If hydropower is constructed in the future by the Government no additional flowage rights should be required from the Town of Webster. If the Development was through the FERC applicant it is customary for FERC to allow the applicant to utilize Government property with a MOU being consummated between the applicant and the Government agency. Any other real estate interest necessary for the project is the responsibility of the applicant.

RESERVOIR CLEARING

The selected hydropower alternatives proposed two different pool elevations for hydropower generation. The pool level for the submersible hydropower alternatives at Elevation 530 feet NGVD would inundate an additional 26 acres of the impoundment area. Based on a visual inspection it was assumed that 50 percent of the area would require clearing. The conventional hydropower alternatives would require the creation of a permanent pool at Elevation 543 feet NGVD. This pool level would inundate 645 additional acres of the reservoir area. Complete clearing costs for the lower pool would be approximately $13,000 and approximately $500,000 for the higher pool. For this report is was assumed that only the trees and slash would be removed and the tree stumps and topsoil would be left in place. The cost of the tree and slash removal would be recovered from the value of the timber harvest. No estimates for reservoir clearing are included in the alternative cost estimates. Water quality investigations would be required to assess the environmental inpact of leaving the topsoil and tree stumps in place. If negative environmental impacts are anticipated, then complete clearing would be required.

REAL ESTATE

The Real Estate requirements associated with hydropower development at the Corps of Engineers facility consists of the procurement of all lands, easements and rights-of-way not under the ownership of the Federal Government. Alternatives 1 thru 3 would be constructed entirely on government land and would not require any additional Real Estate acquisitions. Alternatives 4 and 5 consist of a powerhouse located downstream of the flood control project connected to the dam by a steel penstock. The penstock alignment would be an open cut except for the area that passes beneath Route 127. The alignment would pass through and sever a one acre parcel along Route 127 thus rendering it useless. The powerhouse would be located on lands of the town of Webster and will affect two acres of land adjacent to the river. Each of the affected areas would require fee acquisitions. A permanent right-of-way access is necessary for ingress and egress to the powerhouse. The right-of-way would commence on the easterly side of Route 127 and extend approximately 200 feet in an easterly direction. This access route would be 25 feet wide and contain 5,000 square feet. A temporary construction easement would be required along the penstock alignment adjacent to Warner Road. The total Real Estate costs for these alternatives has been estimated at $26,000.

V. ASSESSMENT OF HYDROPOWER ALTERNATIVES

Economic Analysis

Each of the five alternatives was evaluated over a life span of 50 years to determine the total annualized cost of the project. The total cost for each alternative includes an allowance for engineering and design, administration, supervision, inspection and overhead (E&D, S&A) and for interest during construction (IDC). E&D and S&A values were determined using standardized curves relating total cost to percentage of total construction cost. IDC values for this feasibility investigation were determined assuming straight line expenditures over the entire project construction period. The total investment cost for each of the alternatives was then amortized using the Fiscal Year 1986 Federal interest rate of 8-5/8 percent to determine the annual cost of the project. Values for operation and maintenance (O&M) and replacement costs were added to establish the project's total annual costs. The costs estimates are based on January 1986 price levels. Table 5 presents cost estimates for each of the alternatives.

The conceptual basis for evaluating the benefits from energy produced by hydroelectric power plants is society's willingness to pay for these outputs. This value of energy is generally the market value of electricity in the region of the country under investigation. The Federal Energy Regulatory Commission (FERC) has the task of assigning values on the power to be produced by a hydropower development under consideration of the Corps of Engineers. The FERC accomplishes this utilizing one of the following methods:

(1) Estimate the resource cost of the most likely thermal alternative to be implemented in the absence of hydropower development.

(2) Perform a "life cycle cost" analysis for the most likely alternative in which projected fuel cost increases are factored into the total resource cost.

(3) Measure the "displaced" or "avoided" energy cost that the hydropower addition will accomplish in the existing electrical generation system.

The proposed plans of development at Blackwater Dam are small in nature and contain no dependable capacity. It is evident that a thermal alternative would not be built in the absence of the constuction of a hydropower plant at Blackwater Dam. Based on these factors a "most likely alternative" or a "dependable capacity life cycle analysis" would be impractical. It was determined that the displaced energy analysis would be the most applicable methodology for this project. The displaced energy method estimates the cost of the energy that the hydropower addition at Blackwater Dam would displace from the existing generation system. The methodology for the displaced energy cost analysis is based on the Water

TABLE 5
BLACKWATER DAM HYDROPOWER STUDY
HYDROPOWER ALTERNATIVES
COST ESTIMATES
APRIL 1986 PRICE LEVELS

ITEM	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Excavation General				$10,000.00	$10,000.00
Excavation Rock	$8,000.00	$12,000.00	$28,000.00	$215,000.00	$236,000.00
Mass Concrete	$26,000.00	$36,000.00	$67,000.00	$150,000.00	$155,000.00
Reinforced Concrete	$78,000.00	$66,000.00	$32,000.00	$60,000.00	$64,000.00
Steel Penstocks, Liners etc.			$59,000.00	$806,000.00	$821,000.00
Trashrack	$12,000.00	$22,000.00	$10,000.00	$12,000.00	$21,000.00
Hydraulic Gate, Installed			$113,000.00		
Sluice Gates	$15,000.00	$30,000.00			
Turbine, Installed	$122,000.00	$243,000.00	$1,050,000.00	$1,250,000.00	$2,175,000.00
Misc Mechanical Equip.			$65,000.00	$110,000.00	$120,000.00
Misc incl stairs, stop logs etc.			$30,000.00	$40,000.00	$45,000.00
Station Elec Equip	$21,000.00	$30,000.00	$42,000.00	$440,000.00	$560,000.00
Interconnection with Utility	$23,000.00	$23,000.00	$23,000.00	$30,000.00	$30,000.00
Raise Roads etc in Perm pool					
Clear & Fill ROW/Patch Hwy				$10,000.00	$10,000.00
Reservoir Clearing					
Access, Crane for construction			$80,000.00		
Access	$10,000.00	$10,000.00		$5,000.00	$5,000.00
Control of Water	$55,000.00	$55,000.00	$135,000.00	$10,000.00	$10,000.00
Site Preparation	$5,000.00	$5,000.00	$10,000.00	$10,000.00	$10,000.00
SUBTOTAL	$375,000.00	$532,000.00	$1,744,000.00	$3,158,000.00	$4,272,000.00
CONTINGENCY 25%	$94,000.00	$133,000.00	$436,000.00	$789,000.00	$1,068,000.00
TOTAL	$469,000.00	$665,000.00	$2,180,000.00	$3,947,000.00	$5,340,000.00

Resources Council's task force report entitled, "Implementation Procedures for Evaluating Hydropower Benefits," dated December 1981.

The methodology employed by FERC in deriving the economic value of the energy produced by the selected hydropower alternatives was based on the present market value of the thermal generation which would be replaced by the new installation. The value placed on the energy produced at a particular project is in direct relationship to the annual cost of the energy generation it would replace. The annual load duration curves for New England were synthesized from data contained in the Northeast Power Coordinating Council (NPCC), Long Range Coordinated Bulk Power Supply Programs report, and the load duration curves provided by the New England Power Exchange (NEPEX). The type of generation displaced was then determined from the capacity band stackings on the annual load duration curve. The projected capacity mix available from the NPCC reports through the year 2002. After 2002 it was assumed that there would be no further changes in the types of generation displaced. The load curve analysis determined that the energy being displaced by these hydropower plants would be oil-fired generation. The value of future energy was established by projecting the existing values to the year 2010 using oil projections provided to the U.S. Department of Energy by the Energy Information Administration. The energy values were then adjusted to reflect the difference in the escalation rate between the cost of fuel and the general rate of inflation. The values were then brought back to present value using the anticipated rate of future inflation. The displaced energy values calculated for Blackwater Dam in Webster, New Hampshire are shown in Table 6.

TABLE 6
BLACKWATER DAM HYDROPOWER STUDY
AT-MARKET POWER VALUES

	Combustion Turbines	Cycling	Coal	Base	Load	Coal	
Plant factor (%)	10	20	30	40	50	60	70
Displaced Energy							
Energy (mills/kWh)	201	201	187	187	187	187	171

The calculated displaced energy values were applied to the average energy generated at each hydropower alternative to determine the expected annual energy benefits for each of the projects. Economic justification was determined by comparing the average annual energy benefits to the total annual costs. The resulting benefit to cost ratio must exceed unity for an alternative to be considered economically viable. A summary of the economic evaluation for each of the alternatives is shown in Table 7.

TABLE 7
BLACKWATER DAM HYDROPOWER STUDY
ECONOMIC EVALUATION OF ALTERNATIVES

Project Description	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Installation scheme	Submer (step)	Submer (2 units)	At Dam	D/S 1 Unit	D/S 2 Units
Net Head (ft)	10	10	28	64	64
Pool Elevation	530 NGVD	530 NGVD	543 NGVD	543 NGVD	543 NGVD
Installed Capacity (Kw)	55.6	111.5	615	1700	1700
Avg Annual Energy (mWh)	302,000	400,000	1,892,000	4,067,000	5,093,000
Plant factor (%)	0.64	0.46	0.38	0.31	0.38
Cost Analysis					
First Cost	$375,000	$532,000	$1,744,000	$3,158,000	$4,272,000
Contingencies	$94,000	$133,000	$436,000	$789,000	$1,068,000
Construction Cost	$469,000	$665,000	$2,180,000	$3,947,000	$5,340,000
Real Estate				$26,000	$26,000
E&D, S&A	$82,000	$117,000	$382,000	$696,000	$939,000
Total Project Cost	$551,000	$782,000	$2,562,000	$4,669,000	$6,305,000
Interest During Const	$12,000	$17,000	$110,000	$402,000	$543,000
Total Investment	$563,000	$799,000	$2,672,000	$5,071,000	$6,848,000
Annual Cost Analysis					
Interest & Amortization	$48,000	$68,000	$228,000	$432,000	$584,000
Operation & Maintanence	$1,000	$1,000	$13,000	$16,000	$25,000
Replacement	$1,000	$1,000	$10,000	$10,000	$10,000
Total Annual Cost	$50,000	$70,000	$251,000	$458,000	$619,000
Benefit Analysis					
Avg Annual Energy (kWh)	302,000	400,000	1,892,000	4,067,000	5,093,000
Energy Value (mills/kWh)	187.00	187.00	187.00	187.00	187.00
Annual Energy Value	$57,000	$75,000	$354,000	$760,000	$953,000
Economic Analysis					
Total Annual Cost	$50,000	$70,000	$251,000	$458,000	$619,000
Total Annual Benefit	$57,000	$75,000	$354,000	$760,000	$953,000
Benefit/Cost Ratio	1.14	1.07	1.41	1.66	1.54
Net Annual Benefit	$7,000	$5,000	$103,000	$302,000	$334,000
Cost of Energy (mills/kWh)	165.56	175.00	132.66	112.61	121.54

The calculated FERC power values for the Corps' Blackwater Dam in Webster, New Hampshire were compared to the regional private power recovery rates to assess the accuracy of the FERC values. The PSNH has a policy of pursuing all viable new alternative energy sources for the purpose of reducing their dependency on foreign oil and increasing their total generating capability. The value of the purchased energy is based on PSNH's Incremental Energy Cost (IEC), which is equivalent to their marginal cost of providing energy for the specific hour being credited. The marginal cost, of any hour, is the total energy cost of the most expensive unit or purchased energy supplying a portion of PSNH's load during that hour. PSNH's long-term contract payments are based on IEC's as they actually occur. For planning purposes, PSNH provides estimates of levelized values of the projected IEC's for contract periods up to 30 years with on-line dates up to 1989.

The PSNH energy values were projected to a 50-year contract period to compare with the FERC power values. The relationship between the PSNH's power values and the contract period value was determined by extrapolating the plotted PSNH data. The PSNH values were also extrapolated to include on-line dates beyond 1989. A graphic analysis of the data indicated that the relationship between the energy values and future start date approximated a second degree polynominal. Quadratic Interpolation was used to develop a relationship between the power values and the on-line dates. The PSNH power values, including the extrapolated values, are presented in Table 8.

TABLE 8
BLACKWATER DAM HYDROPOWER STUDY
PSNH CONTRACT POWER VALUES
(Mills/kWh)

Term (yrs)	1988 Start	1989 Start	1990 Start	1991 Start
10	6.74	7.46	8.26	9.14
15	7.94	8.72	9.75	10.78
20	9.21	10.17	11.24	12.42
30	11.68	12.87	14.22	15.70
50	16.62	18.28	20.18	22.26

A comparison of the FERC power values with the PSNH long-term contract rates was based on the assumption that a project at Blackwater Dam could not be constructed before 1990. The PSNH projected rate for a 50-year contract with a start date of 1990 was slightly greater than the selected FERC power values. The proximity of the two independently calculated energy values indicated that the FERC power values are reasonable for the area.

In early 1986, the global price of oil dropped dramatically due to overproduction in the foreign market. Both the FERC and PSNH power rates were based on oil price projections made prior to the sharp price decline.

The long term impact of this temporary price reduction on the future value of energy is difficult to forecast. For this report, it was assumed that the present fluctuation in the world oil market is temporary and will not significantly impact the existing long range energy forecasts.

ARCHAEOLOGICAL IMPACTS

The creation of either a 15-foot (Elevation 530) or 28-foot pool (Elevation 543) would affect 12 historic period sites above the dam. While current flood control operations do not appear to be significantly damaging these sites, permanent inundation could result in severe effects. Further, much of the area that would be subject to inundation has a high potential for the preservation of any prehistoric sites.

Impacts from the construction of the proposed hydropower installations would only be associated with the alternatives utilizing downstream powerhouses and the 1,150 foot penstock. Based upon current data, it appears that a historic site could be impacted by the construction of the downstream powerhouse. In mid-19th century and perhaps earlier, several structures stood within the area of the proposed overland penstock alignment. Further, a high potential for prehistoric sites occurs within all areas adjoining the dam and not subject to historic period disturbance. Any potential historic or prehistoric sites in the immediate vicinity of the existing structure were heavily disturbed by the construction of the dam in 1941.

ENVIRONMENTAL IMPACTS

The implementation of a permanent pool at Elevation 543 feet NGVD (28-foot pool) would eliminate about 9 miles of high quality cold water riverine aquatic habitat and could potentially eliminate its associated riverine cold water fishery and replace it with approximately 775 acres of permanent pool with its warm water habitat, capable of supporting appropriate warm water species, possible capable of seasonal support of cold water species. Reducing the pool to Elevation 530 feet NGVD (15-foot pool) would eliminate only 0.6 miles of high quality cold water riverine aquatic habitat creating a 25-acre warm water permanent pool. Alternatives 4 and 5 would bypass approximately 1,000 feet of river. It would be essential to maintain a sufficient minimum flow in this part of the river at all times to assure that there would be no serious effects on the aquatic ecosystem in this reach.

The creation of the 645 or 25 acre permanent pools would permanently inundate all vegetation within them. Areas undergoing more frequent inundation during flood control operations would experience the killing of less flood tolerant species and a gradual shift in composition toward more tolerant species.

Wildlife associated with the permanently inundated habitats would perish or move onto adjacent lands where increased competition would cause mortality of some. Displacement and some mortality would also take place in areas of increased frequency of inundation. The population shifts may cause overcrowding and further mortality in some areas where the habitat carrying capacity has been reached. In addition, construction of the penstock associated with Alternatives 4 and 5 would eliminate terrestrial habitat along the penstock route and displace any inhabitants.

The terrestrial habitat would gradually grow over after construction. Terrestrial inhabitants might also avoid areas adjacent to the penstock during construction alternatives.

Since there are no currently listed Federal threatened or endangered species in the project area, no impacts would be anticipated from implementation of the project.

RECREATIONAL IMPACTS

The 28 foot deep, 775-acre pool, which would be created by the Elevation 543 feet NGVD pool, would have an adverse impact on existing recreational use of the reservoir area. Approximately one-half of the existing 20 mile snowmobile trail system would be eliminated. About nine miles of high quality cold water trout fishing habitat would be lost. The project lands that would be lost include wetlands, agricultural lands, wildlife habitat including some woodcock and grouse areas and local swimming holes.

The proposed 775-acre pool would offer the potential for new water oriented recreation development to partially offset the loss of existing resources. Development could include a swimming beach, boat launch access points and additional day use areas. When the original Blackwater Dam Master Plan was prepared in 1967, however, there was overwhelming opposition to the creation of a 2,020-acre recreation lake and attendant recreation facilities including camping areas, swimming beaches and boat launching ramps. Meetings held with the selectman of the Town of Webster in 1983 indicated that there is still opposition to creation of any pool at Blackwater Dam that might result in increased recreation activity.

The creation of the 15-foot, 25-acre lake pool associated with the submersible installation, Alternatives 1 and 2, would have little adverse impact on existing recreation. No areas of passive recreation would be lost. No snowmobile trails would be affected. Only the 0.6 mile segment of the river upstream of the dam would be lost as a cold water riverine trout fishery. Little opportunity would be afforded for expanded water oriented recreation on such a small and narrow pool.

WATER QUALITY IMPACTS

The creation of a permanent reservoir located in back of the dam would result in a modification of the erosion pattern during flood control operations. Areas less frequently inundated may be reached by the waters more often and provide increased opportunity for erosion, particularly in the early years and operations. Erosion at the pool could be significant, but should be restricted to a narrow area along the shore due to the small fluctuations associated with hydropower operations.

The development of the proposed 28-foot deep pool for hydropower generation should cause only minimal change in the existing water quality. The reasoning for this assumption is based on several items, which include the relatively shallow depth of the pool (less than 35 feet deep), the short hydraulic detention time (about 8 days under average flow conditions) and the fact that the river is naturally sluggish though the project area. As a result of the shallow depth and short detention time, there should be little if any thermal stratification effect in the reservoir and it is unlikely that detailed thermal stratification modelling or a multiple level withdrawal outlet works would be required. Problems may occur on the short term basis with suspended solids and turbidity if the vegetation and topsoil are not stripped from the pool area prior to impoundment, or if considerable erosion takes place during flood control or hydropower operations. The creation of the 15 feet pool would cause similar water quality impacts of a lesser magnitude.

SELECTED PLAN

The principal purpose for the development of the hydropower potential at Blackwater Dam is the positive contribution to the national economic development. Federal guidelines state that the plan which maximizes the net economic benefit (NED Plan) should be the selected plan of development unless there is sufficient justification for deviation. Net benefits for a hydropower project is defined as the difference between the expected annual value of the energy produced and the total investment cost amortized over the life of the project.

The economic evaluation for a hydropower investigation should consist of determining the benefit to cost ratio, the net economic benefits, and the levelized cost of each unit of energy produced for each of the alternatives. In order to do a complete economic analysis, all three indicators must be looked at carefully. When analyzing the economic viability of a hydropower project, the benefit to cost ratio can be a more valuable indicator than the net benefits. The benefit to cost ratio provides the percent difference between the amortized investment cost of the project and the annual value of the energy produced. The greater benefit to cost ratio provides a larger margin of energy values under which the project would remain economically justified. The net economic benefits are determined by subtracting the amortized cost of the project from the average annual value of the energy. The selection of a project based on this criteria optimizes the cost differential, however, may yield a project that is more sensitive to the unpredictable shifts in the price of energy. The cost of the energy produced is determined by dividing the total investment cost by the average annual energy produced. This value provides the lowest market value of energy which still produces a cost effective project.

The Blackwater hydropower investigation considered five possible hydroelectric developments. The economic analysis showed two alternatives to be superior to the remaining three. Alternative 5 had the greatest net economic benefits with $334,000, however, Alternative 4 had a higher benefit to cost ratio than Alternative 5 by a margin of 1.66 to 1.54. The calculation of the cost of energy showed that Alternative 4 would remain economically justified with energy values as low as 113 mills/kWh compared to 122 mills/kHw for Alternative 5. Given the current instability for the world oil-market, Alternative 4 was chosen as the selected plan based on its lower sensitivity to changes in the market value of energy.

VI. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the findings presented in this report it appears that the addition of a hydroelectric facility at the Corps' Blackwater Flood Control Dam is economically feasible. Five alternative hydropower schemes were developed and evaluated using standard economic criteria. Three of the alternatives propose creating a 28-foot deep permanent pool at Elevation 543 feet NGVD, while the remaining two alternatives would create a pool at Elevation 530 feet NGVD. Both conventional, downstream hydropower developments and submersible installations, located within the dam's impoundment, were considered for this location.

Each of the five alternatives investigated were found to be economically justified using displaced energy values provided by the Federal Energy Regulatory Commission (FERC). Alternative 4 was selected as the recommended plan based on its lower cost of energy produced. The plan that maximized net economic benefits (NED Plan) was Alternative 5, however, this plan was not selected based on its greater sensitivity to energy price fluctuations.

Alternative 4 consists of a powerhouse located on the right bank adjacent to the highway department sand storage area just off Route 127. The powerhouse would be connected to the dam's 16 foot diameter plugged penstock stub by a 1,200 foot long 7 foot diameter penstock. The powerhouse would consist of one standard tube unit with an installed capacity of 1,700 Kw. The project would operate as a run-of-river installation under an effective head of 64 feet and would produce approximately 4,067,000 kWh of energy per year. The project would have a total investment cost of $5,071,000 with a benefit to cost ratio of 1.66 to 1.0.

Preliminary investigations were made on the impacts of the selected alternatives on the Blackwater Dam project. The installation of a hydropower facility with a maximum pool depth of 28 feet would have minimal impact on the flood control project. The creation of a permanent pool represents a small decrease in the project's flood control storage. Preliminary investigations identify this loss as within acceptable limits, however, the primary function of the Blackwater Dam is flood control and any hydropower installation must operate within the constraints of the flood control operation as stated in the Merrimack River Master Manual. The creation of a permanent pool could have some archaelogical, environmental, recreational and water quality impacts on the Corps' project.

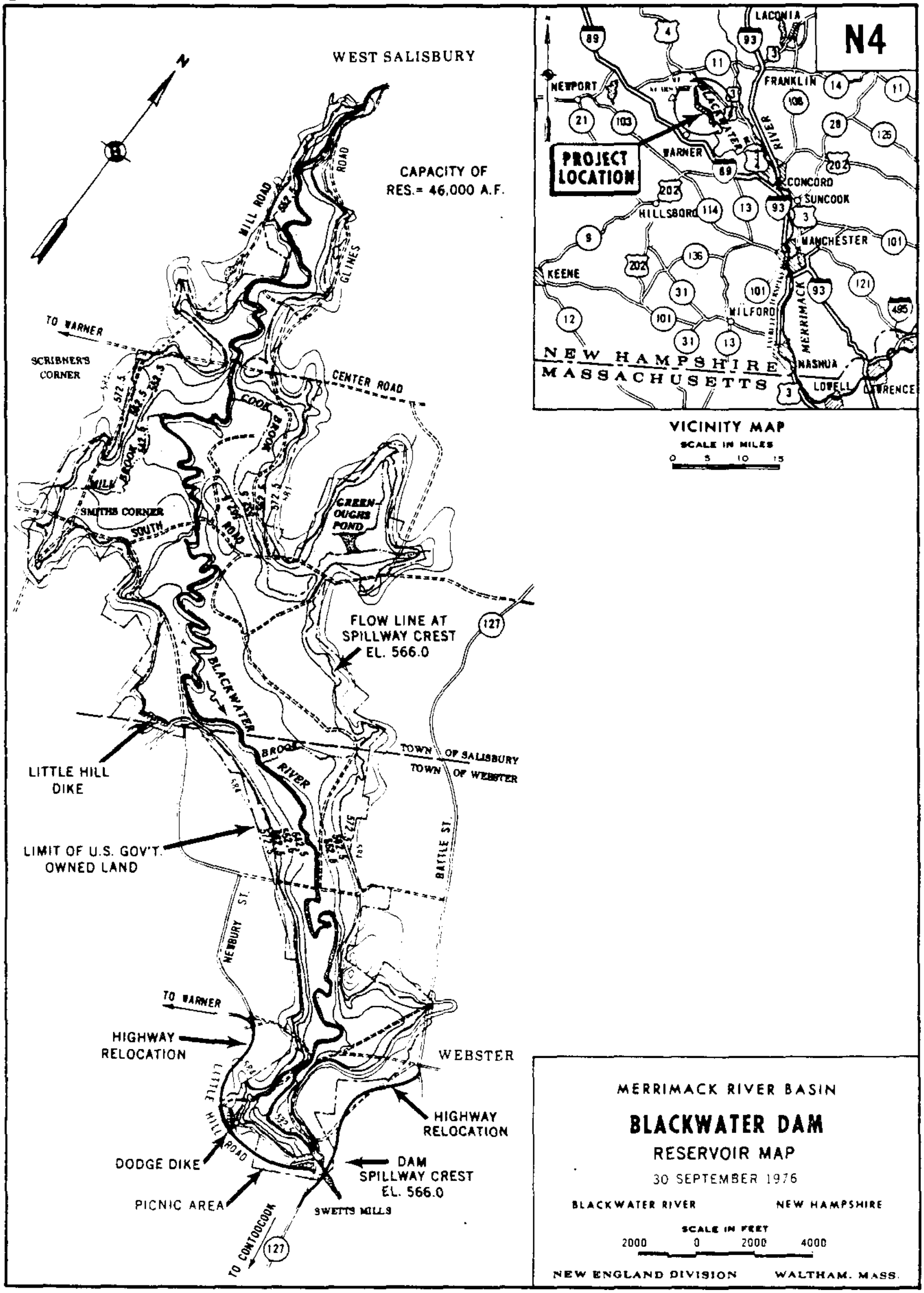
RECOMMENDATIONS

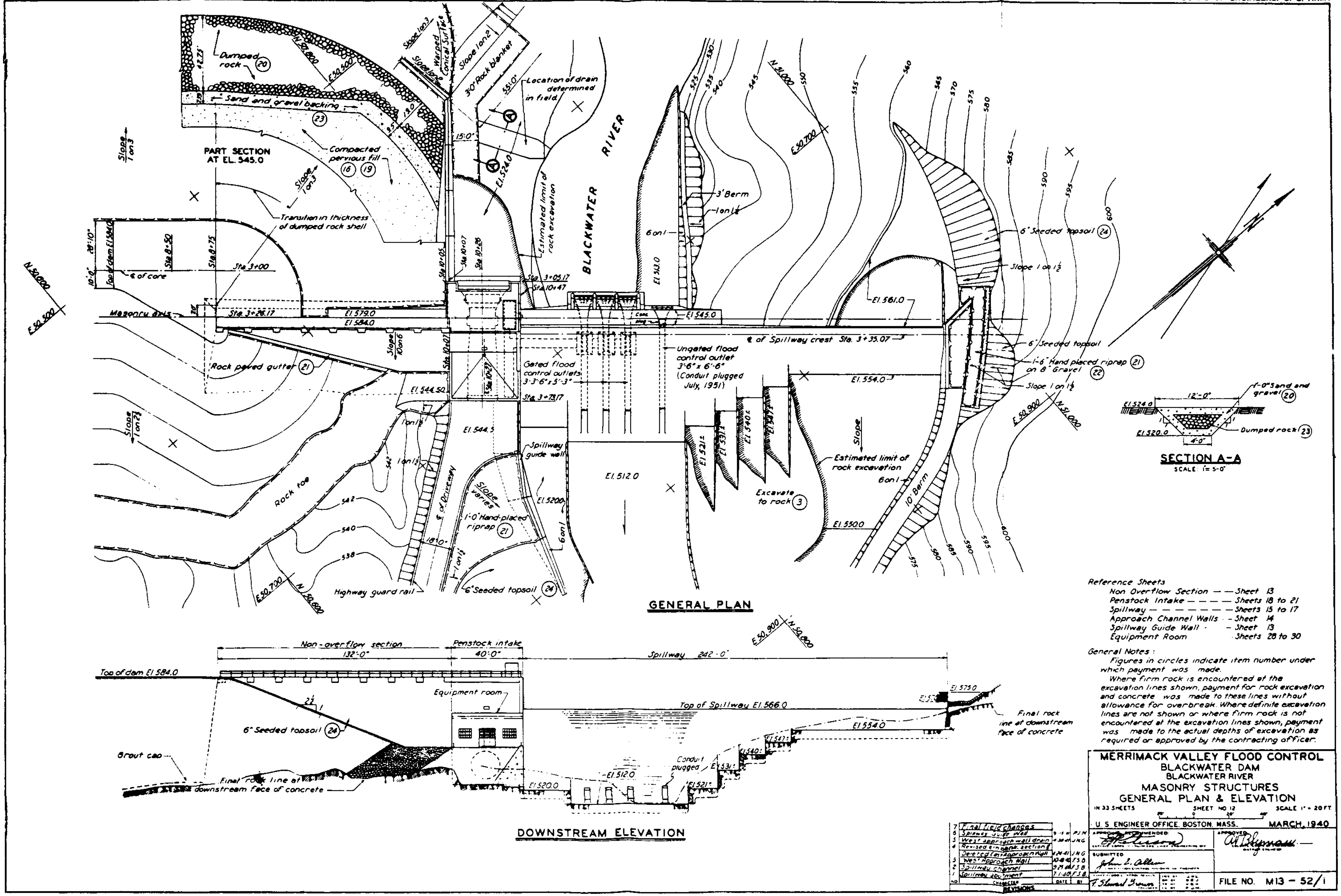
The primary factor used to determine the Federal interest in any water resource project is the project's net contribution to national economic development. The principal criteria for determining a project's net contribution is the relationship between the project's accrued annual benefits versus the project's annual cost. The ratio of annual benefits to annual cost must exceed unity for a Federal interest to exist. Of the five alternatives investigated, all projects had benefit to cost ratios above unity. Alternative 4 was selected based on standard economic criteria.

The current administration's policy is to encourage non-Federal interests to develop the hydropower potential where it is feasible and to only pursue Federal hydropower development where such non-Federal activity is impractical. Hydropower development of the Corps' Blackwater Dam could be pursued under the Federal Energy Regulatory Commission (FERC) procedures, therefore, it is the recommendation of this report that no further study of the Corps' Blackwater Dam be conducted at this time. However, if future development by Non-Federal is considered to be impractical, then, the completion of the feasibility investigation may be warranted.

ACKNOWLEDGEMENTS

This study was conducted by the New England Division, Army Corps of Engineers, under the general supervision of Mr. Joseph L. Ignazio, Planning Division and Mr. Donald W. Martin, Chief, Basin Management Branch. Investigations were performed by an interdisciplinary project team. Presons primarily responsible for the contents of this report are: John Kennelly, Project Manager, project team members: Mark Gieb, Donald Wood, Robert LeBlanc, Anthony Mackos, William Holtham, Ronald DeFilippo, Timothy Beauchemin, Joseph Horowitz. John Wilson, Richard Ring and Edward Fallon.


N4
WEST SALISBURY
CAPACITY OF
RES.= 46,000 A.F.
MILL ROAD
GLINES ROAD
TO WARNER
SCRIBNER'S CORNER
CENTER ROAD
COOK BROOK
MILL BROOK
SMITHS CORNER
SOUTH ROAD
GREENOUGHS POND
FLOW LINE AT
SPILLWAY CREST
EL. 566.0
127
BLACKWATER RIVER
BROOK
LITTLE HILL
DIKE
TOWN OF SALISBURY
TOWN OF WEBSTER
LIMIT OF U.S. GOV'T.
OWNED LAND
BATTLE ST.
NEWBURY ST.
TO WARNER
HIGHWAY
RELOCATION
WEBSTER
LITTLE HILL ROAD
HIGHWAY
RELOCATION
DODGE DIKE
DAM
SPILLWAY CREST
EL. 566.0
PICNIC AREA
SWETTS MILLS
TO CONTOOCOOK
127
PROJECT
LOCATION
LACONIA
NEWPORT
FRANKLIN
WARNER
CONCORD
SUNCOOK
HILLSBORO
MANCHESTER
KEENE
MILFORD
NASHUA
LOWELL
NEW HAMPSHIRE
MASSACHUSETTS
MERRIMACK RIVER
VICINITY MAP
SCALE IN MILES
0 5 10 15
MERRIMACK RIVER BASIN
BLACKWATER DAM
RESERVOIR MAP
30 SEPTEMBER 1976
BLACKWATER RIVER
NEW HAMPSHIRE
SCALE IN FEET
2000 0 2000 4000
NEW ENGLAND DIVISION
WALTHAM, MASS.



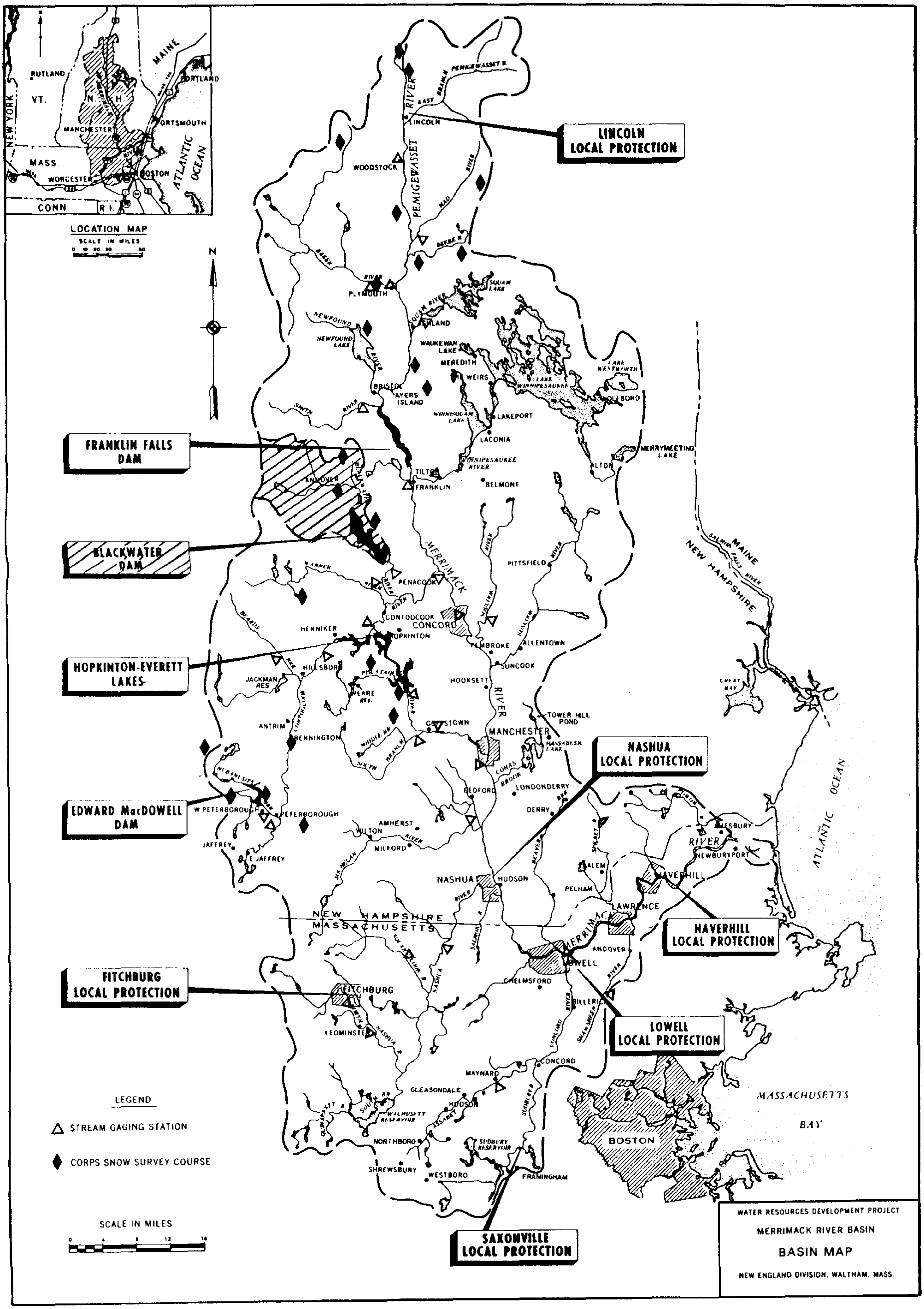
Reference Sheets
- Non Overflow Section — Sheet 13
- Penstock Intake — Sheets 18 to 21
- Spillway — Sheets 15 to 17
- Approach Channel Walls — Sheet 14
- Spillway Guide Wall — Sheet 13
- Equipment Room — Sheets 28 to 30

General Notes:
Figures in circles indicate item number under which payment was made.
Where firm rock is encountered at the excavation lines shown, payment for rock excavation and concrete was made to these lines without allowance for overbreak. Where definite excavation lines are not shown or where firm rock is not encountered at the excavation lines shown, payment was made to the actual depths of excavation as required or approved by the contracting officer.

NO.	CHANGES	DATE	BY
7	Final field changes		
6	Spillway guide wall		PJH
5	West approach wall drain		JNG
4	Revised embank. section		
	Spillway left approach wall		JNG
3	West approach wall		FSB
2	Spillway channel		FSB
1	Spillway abutment	7-1-40	FSB

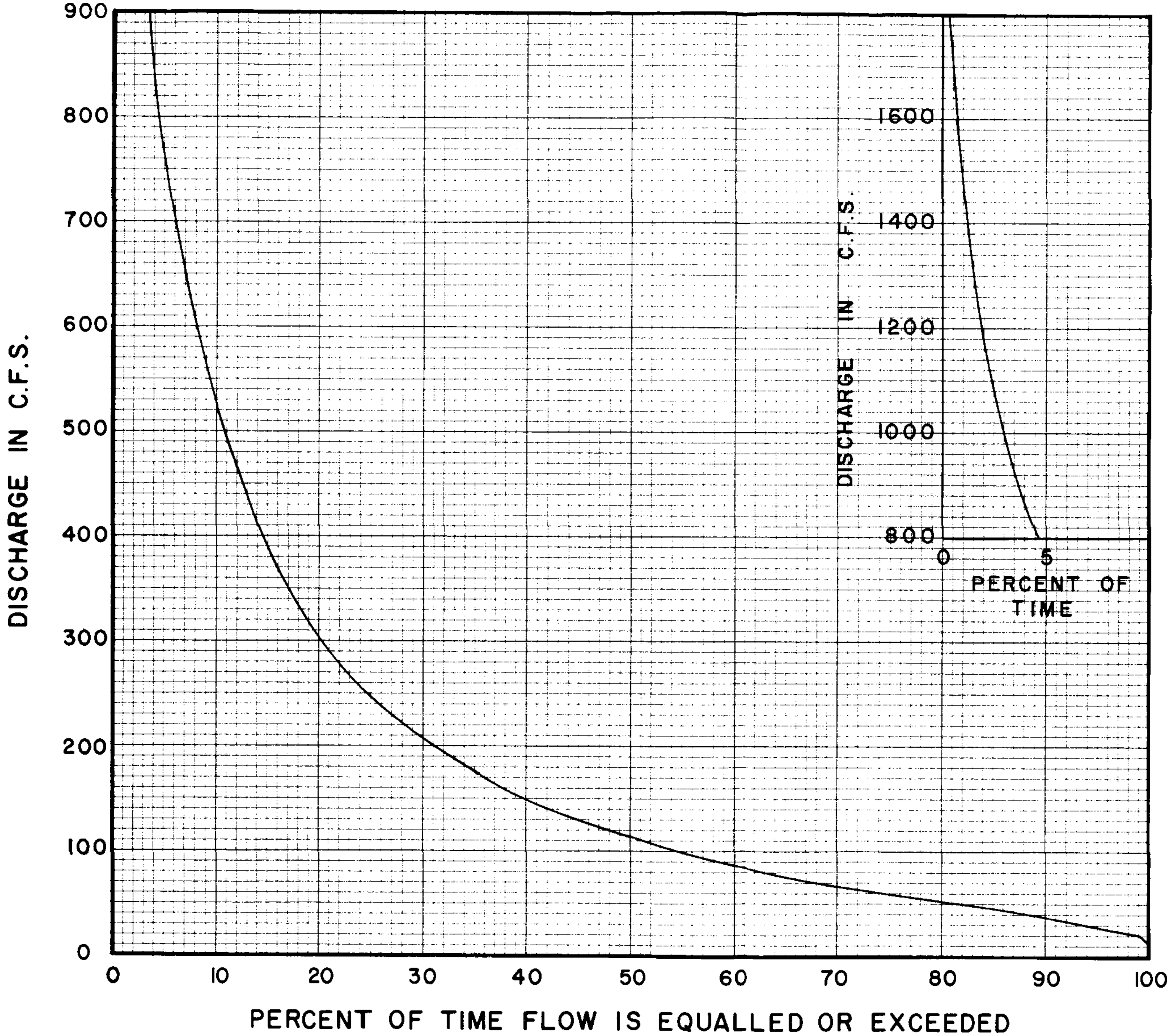
REVISIONS

MERRIMACK VALLEY FLOOD CONTROL
BLACKWATER DAM
BLACKWATER RIVER
MASONRY STRUCTURES
GENERAL PLAN & ELEVATION
IN 33 SHEETS SHEET NO. 12 SCALE 1" = 20 FT.
U. S. ENGINEER OFFICE, BOSTON, MASS. MARCH, 1940
APPROVED RECOMMENDED
APPROVED
SUBMITTED
FILE NO. M13 – 52/1



LINCOLN LOCAL PROTECTION
FRANKLIN FALLS DAM
BLACKWATER DAM
HOPKINTON-EVERETT LAKES
EDWARD MacDOWELL DAM
NASHUA LOCAL PROTECTION
HAVERHILL LOCAL PROTECTION
LOWELL LOCAL PROTECTION
FITCHBURG LOCAL PROTECTION
SAXONVILLE LOCAL PROTECTION
LOCATION MAP
SCALE IN MILES
MAINE
N.H.
VT.
NEW YORK
MASS.
CONN.
R.I.
RUTLAND
PORTLAND
PORTSMOUTH
MANCHESTER
WORCESTER
BOSTON
ATLANTIC OCEAN
N
LEGEND
STREAM GAGING STATION
CORPS SNOW SURVEY COURSE
SCALE IN MILES
0 4 8 12 16
PEMIGEWASSET RIVER
LINCOLN
WOODSTOCK
PLYMOUTH
SQUAM LAKE
NEWFOUND LAKE
BRISTOL
AYERS ISLAND
MEREDITH
WEIRS
LAKE WINNIPESAUKEE
WOLFEBORO
LAKEPORT
LACONIA
TILTON
FRANKLIN
ANDOVER
BELMONT
ALTON
MERRYMEETING LAKE
MERRIMACK
PENACOOK
CONTOOCOOK
CONCORD
HENNIKER
HOPKINTON
PEMBROKE
ALLENTOWN
SUNCOOK
PITTSFIELD
HILLSBORO
JACKMAN RES.
WEARE RES.
HOOKSETT
ANTRIM
BENNINGTON
GOFFSTOWN
MANCHESTER
TOWER HILL POND
MASSABESIC LAKE
LONDONDERRY
DERRY
BEDFORD
W PETERBOROUGH
PETERBOROUGH
JAFFREY
E JAFFREY
WILTON
AMHERST
MILFORD
NASHUA
HUDSON
SALEM
PELHAM
HAVERHILL
AMESBURY
NEWBURYPORT
LAWRENCE
ANDOVER
LOWELL
CHELMSFORD
BILLERICA
NEW HAMPSHIRE
MASSACHUSETTS
FITCHBURG
LEOMINSTER
CONCORD
MAYNARD
GLEASONDALE
HUDSON
WACHUSETT RESERVOIR
SUDBURY RESERVOIR
NORTHBORO
SHREWSBURY
WESTBORO
FRAMINGHAM
BOSTON
MASSACHUSETTS BAY
ATLANTIC OCEAN
GREAT BAY
MAINE
NEW HAMPSHIRE
WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN
BASIN MAP
NEW ENGLAND DIVISION, WALTHAM, MASS.

PLATE 3



NOTES:

DRAINAGE AREA = 129 SQ. MI.
PER. OF RECORD 1919-20
1928-84 (59 YRS.)

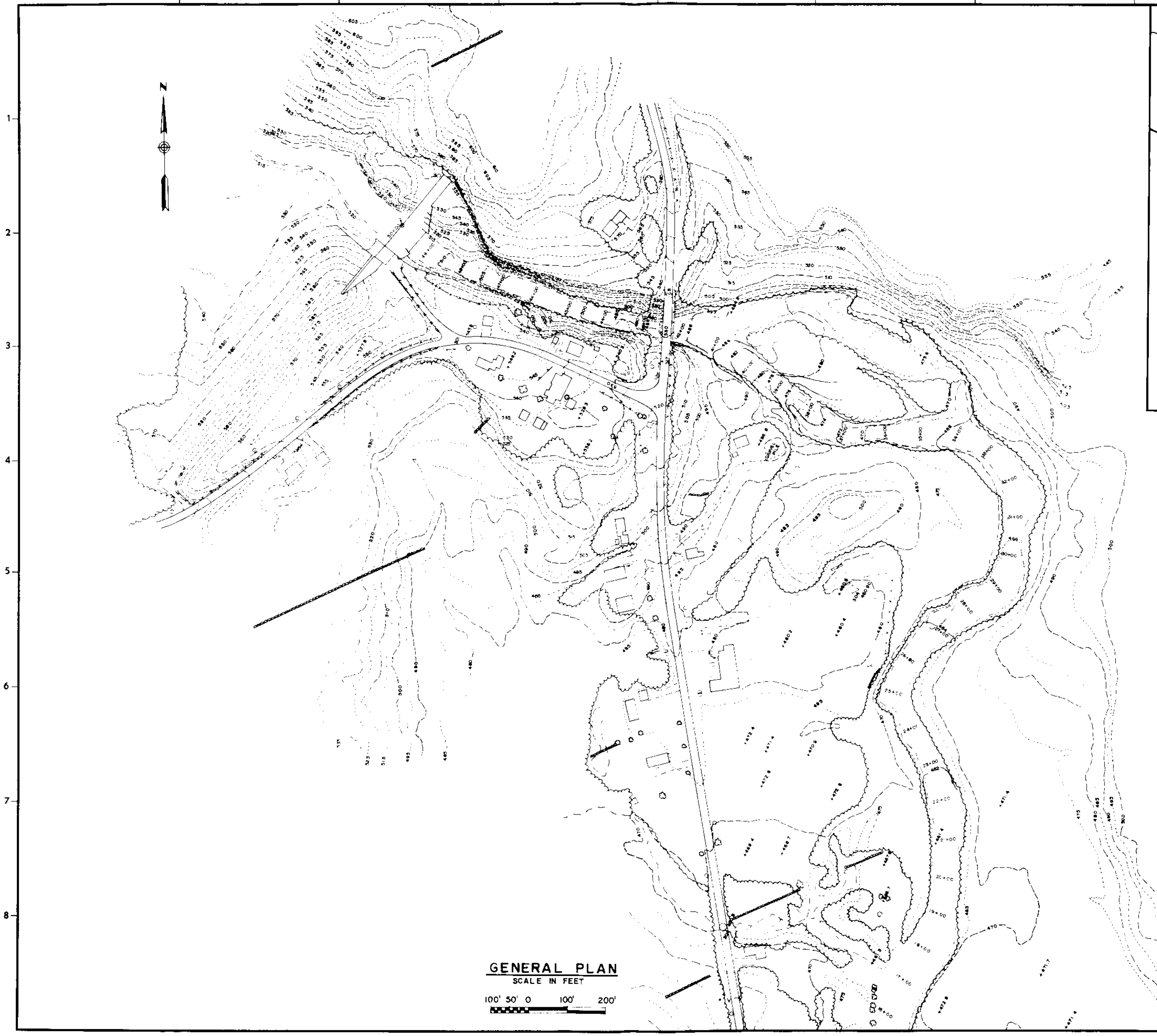
BLACKWATER RESERVOIR
PLACED IN OPERATION
IN 1941.

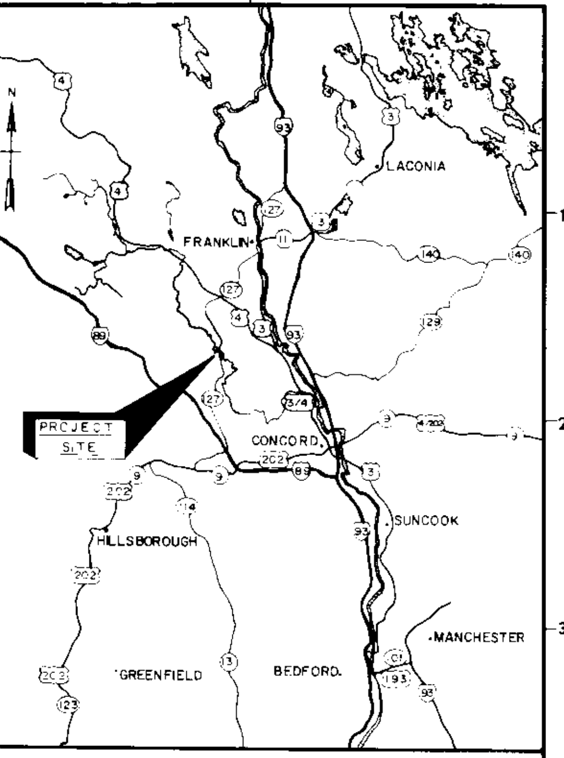
BLACKWATER RIVER
NEAR WEBSTER N.H.

ANNUAL FLOW
DURATION CURVE

HES APRIL 1985

CORPS OF ENGINEERS U. S. ARMY



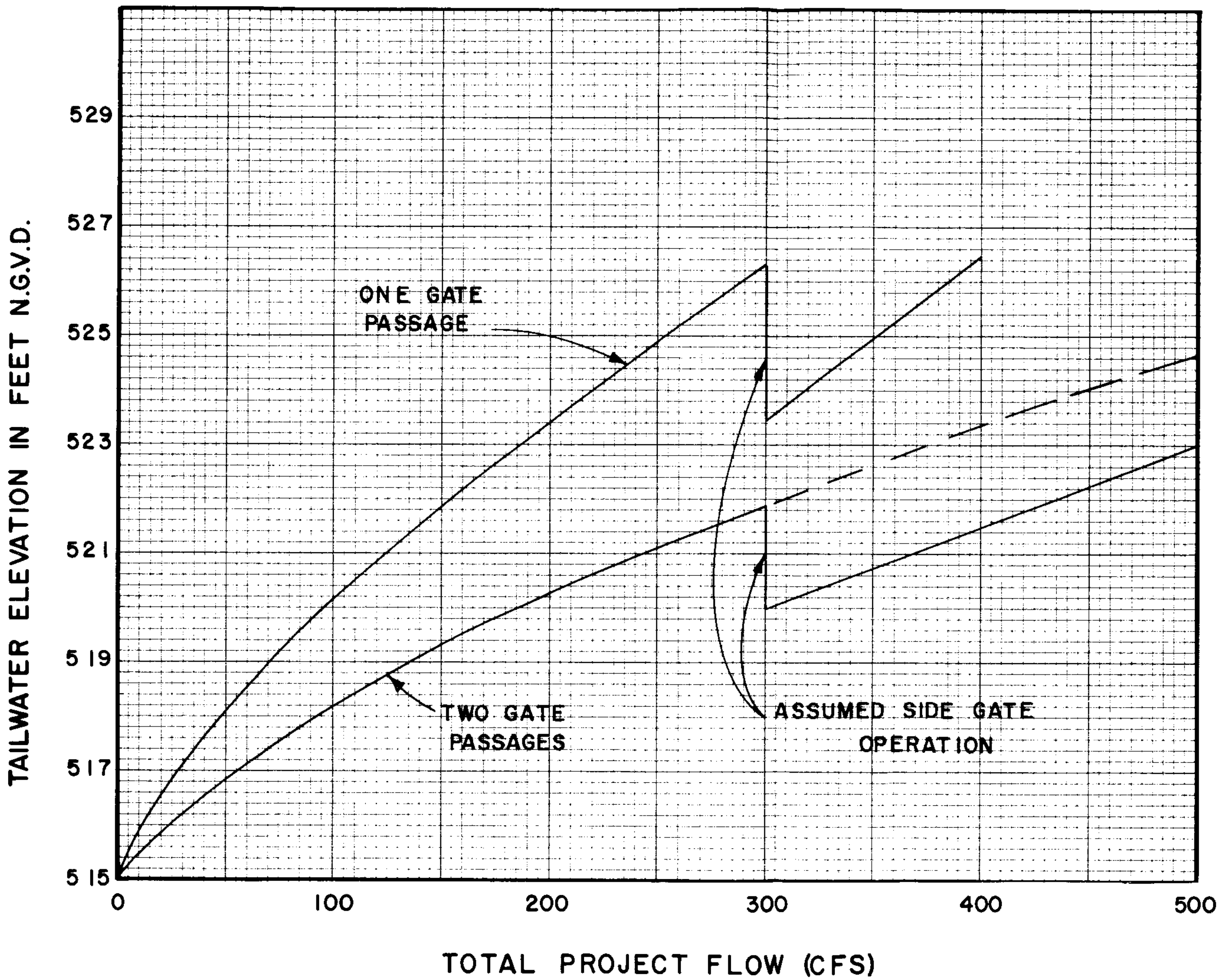


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES INVESTIGATION
MERRIMACK RIVER BASIN
BLACKWATER DAM
PHOTOGRAMMETRIC SURVEY

SCALES AS SHOWN SEPTEMBER 1985

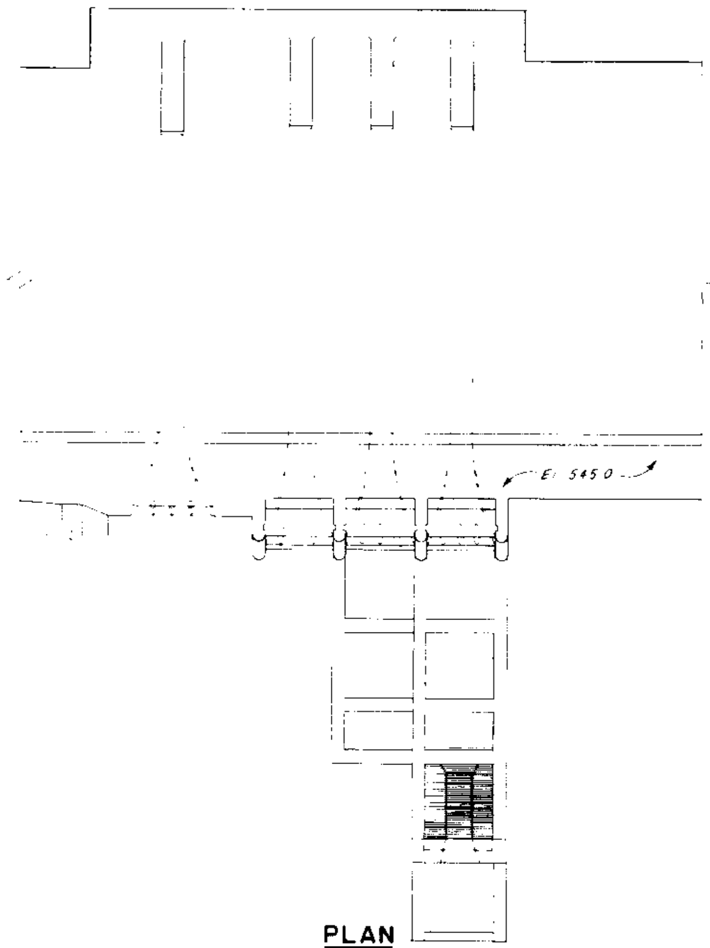
PLATE 5



BLACKWATER RESERVOIR
HYDROPOWER STUDY

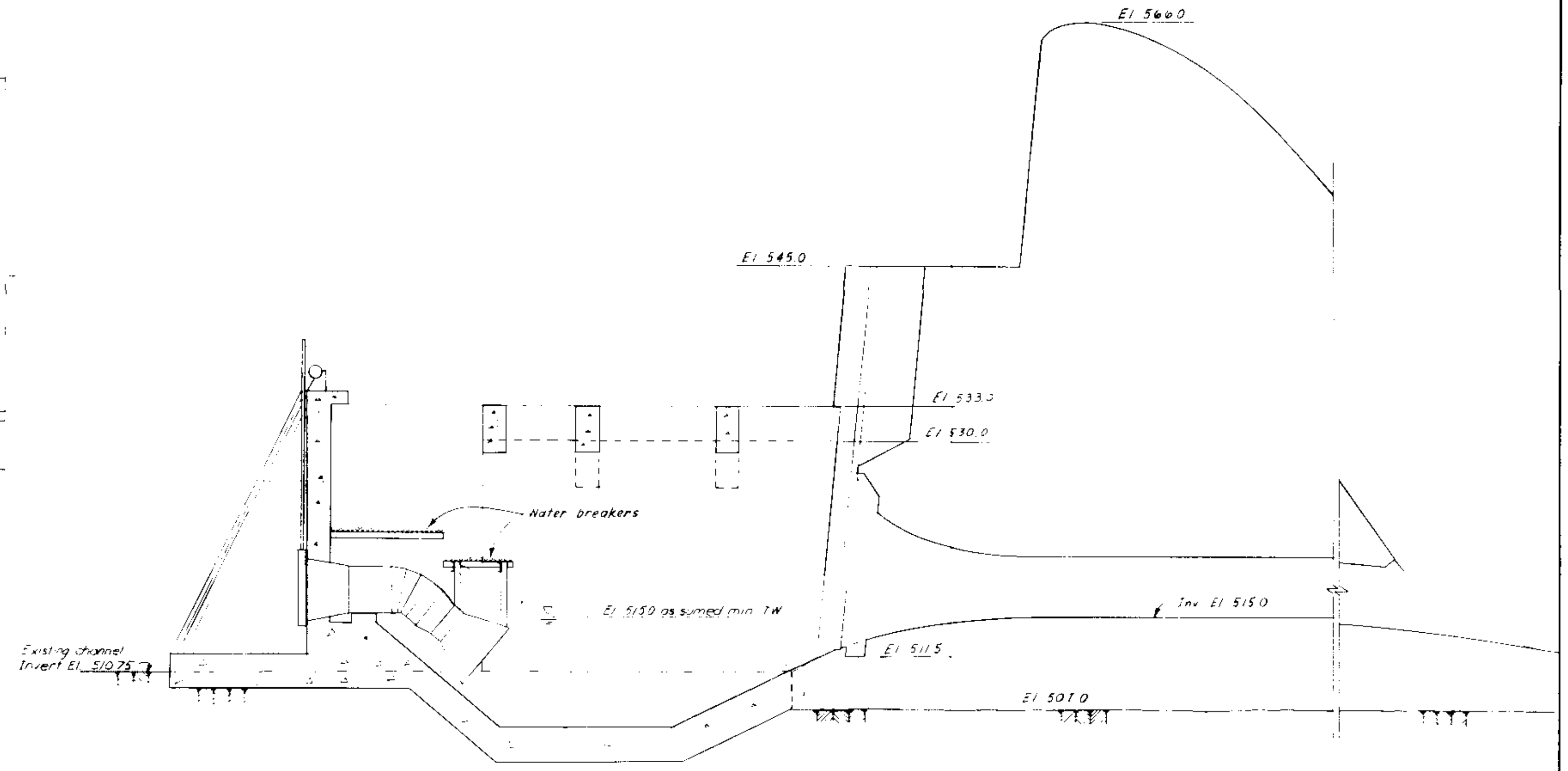
TAILWATER RATING CURVES

HES APRIL 1986



PLAN

SCALE $\frac{3}{32}$" = 1'-0"



SECTION

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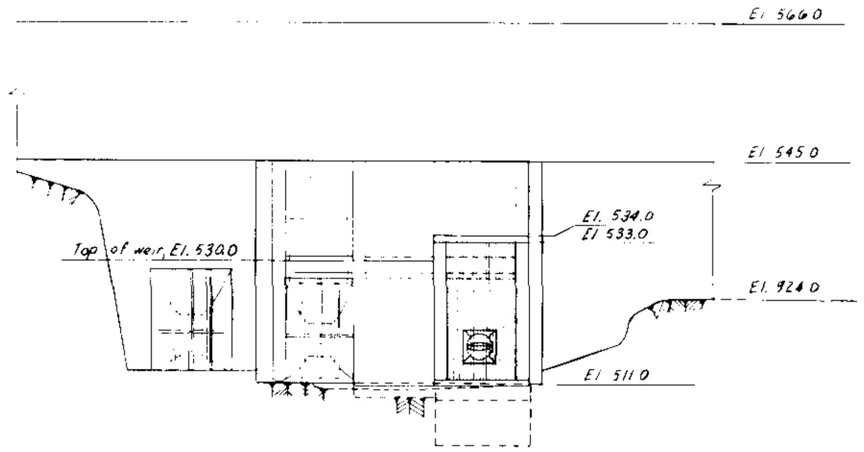


ELEVATION

SCALE $\frac{3}{32}$" = 1'-0"

$\frac{3}{32}$" = 1'-0" 8' 0 8' 16' 24'

$\frac{3}{16}$" = 1'-0" 4' 0 4' 8' 12'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES INVESTIGATION

MERRIMACK RIVER BASIN

BLACKWATER DAM

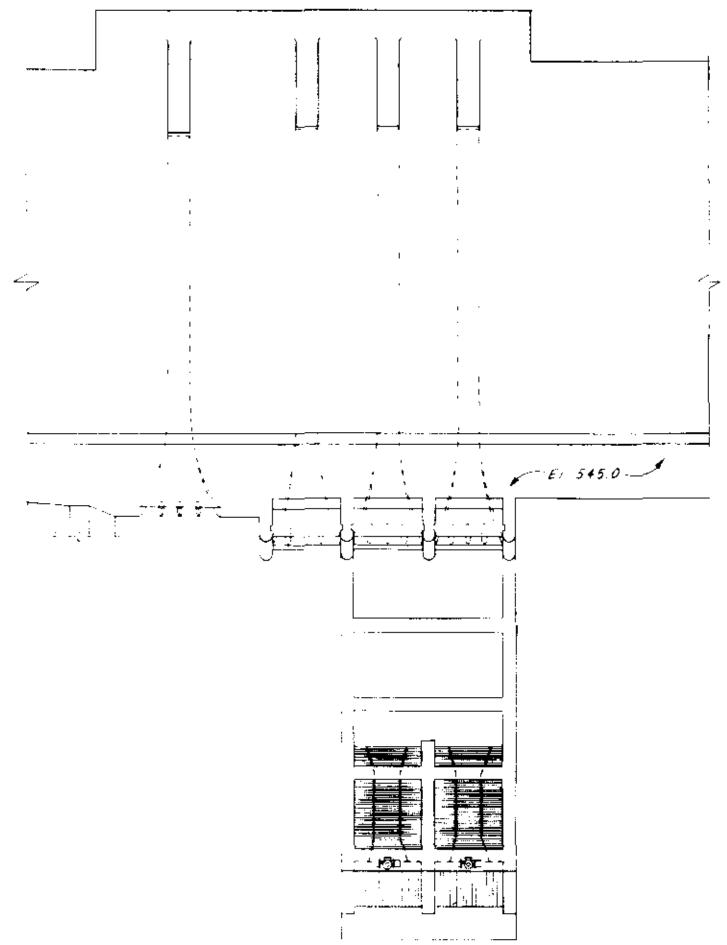
SUBMERSIBLE TURBINE - GENERATOR

ALTERNATIVE I

PLAN AND SECTIONS

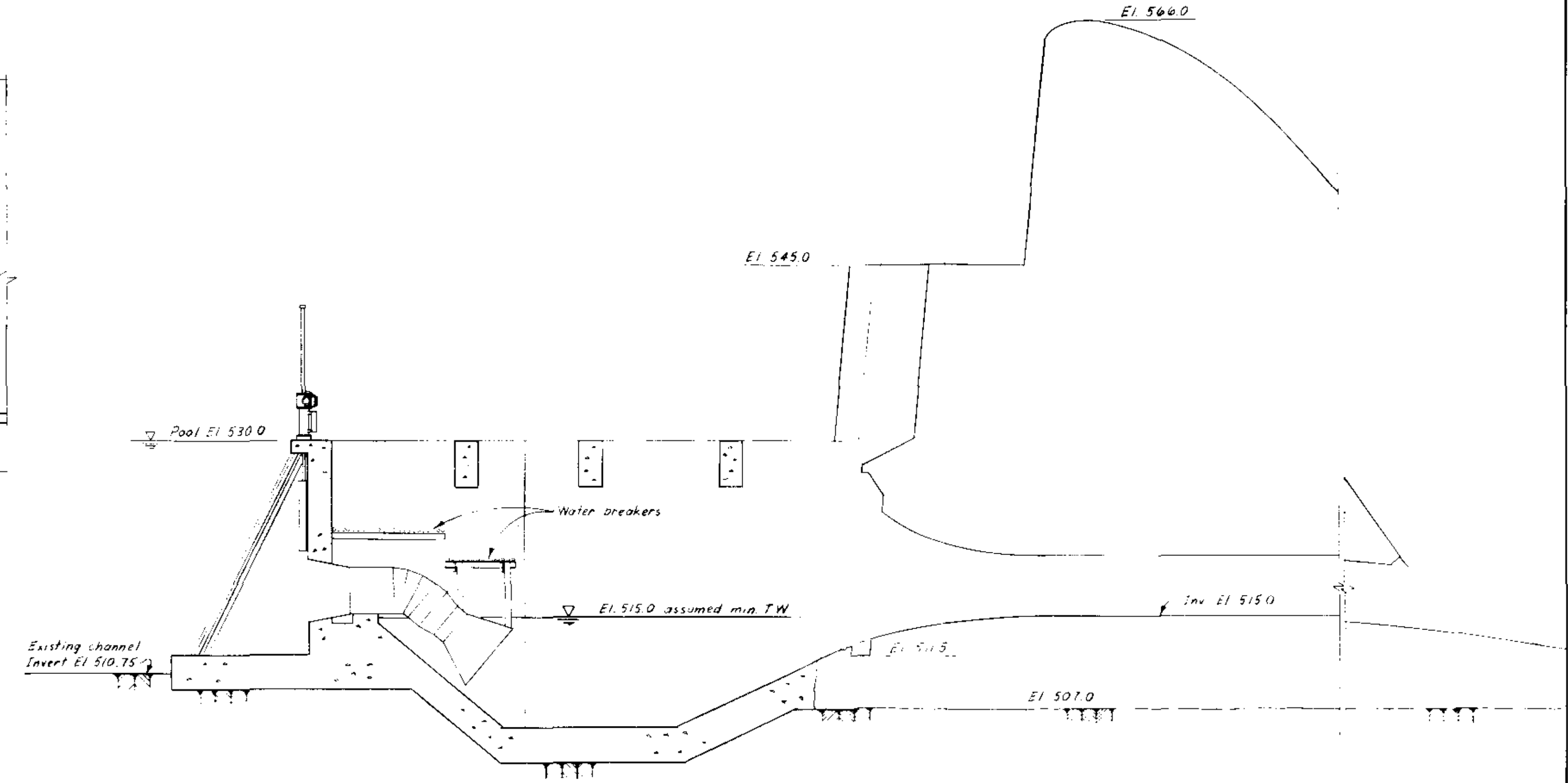
SCALES AS SHOWN AUGUST 1985

PLATE 7



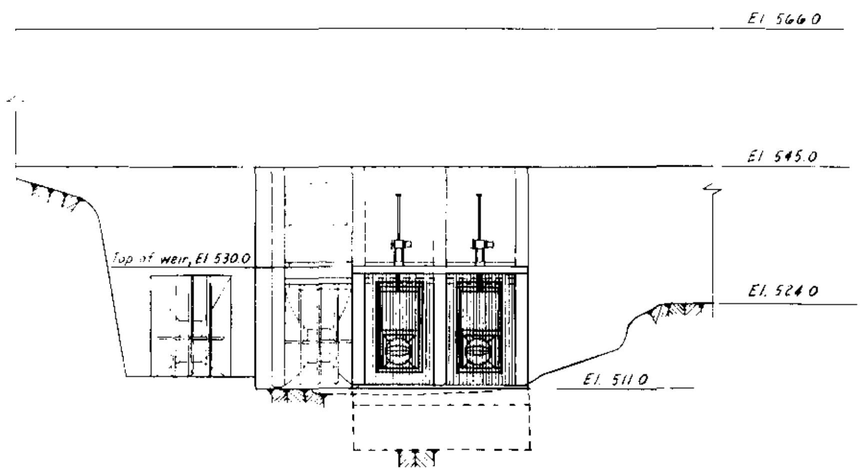
PLAN

SCALE $\frac{3}{32}$" = 1'-0"



SECTION

SCALE $\frac{3}{16}$" = 1'-0"



ELEVATION

SCALE $\frac{3}{32}$" = 1'-0"

NOTE:
1. ELEVATIONS REFER NGVD

$\frac{3}{32}$" = 1'-0" 8' 0 8' 16' 24'

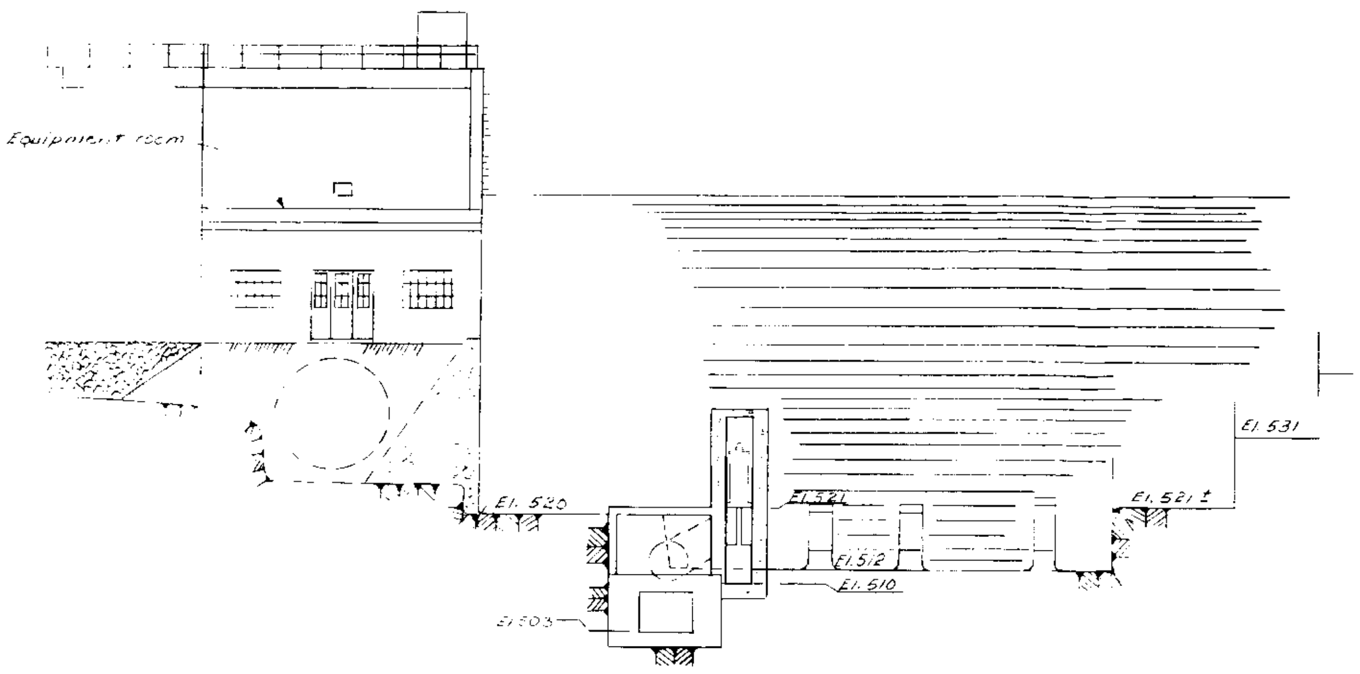
$\frac{3}{16}$" = 1'-0" 4' 0 4' 8' 12'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

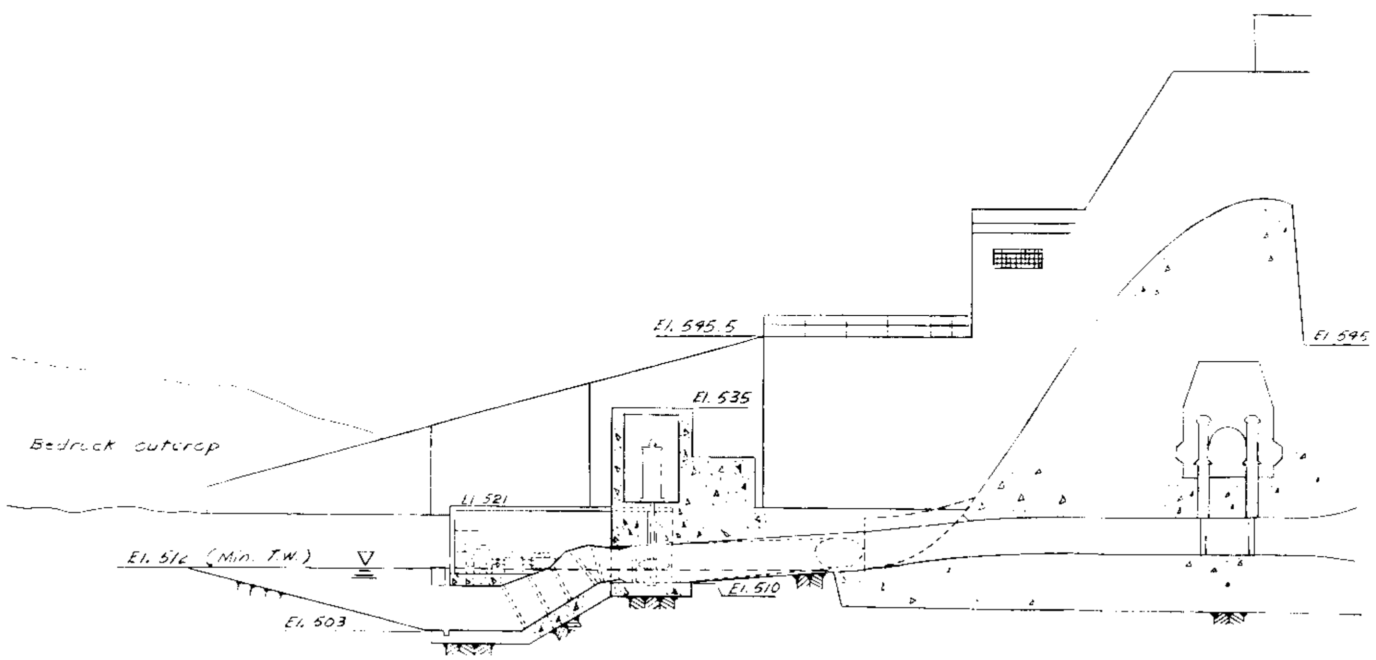
WATER RESOURCES INVESTIGATION
MERRIMACK RIVER BASIN
BLACKWATER DAM
SUBMERSIBLE TURBINE - GENERATOR
ALTERNATIVE 2
PLAN AND SECTIONS

SCALES AS SHOWN | DECEMBER 1985

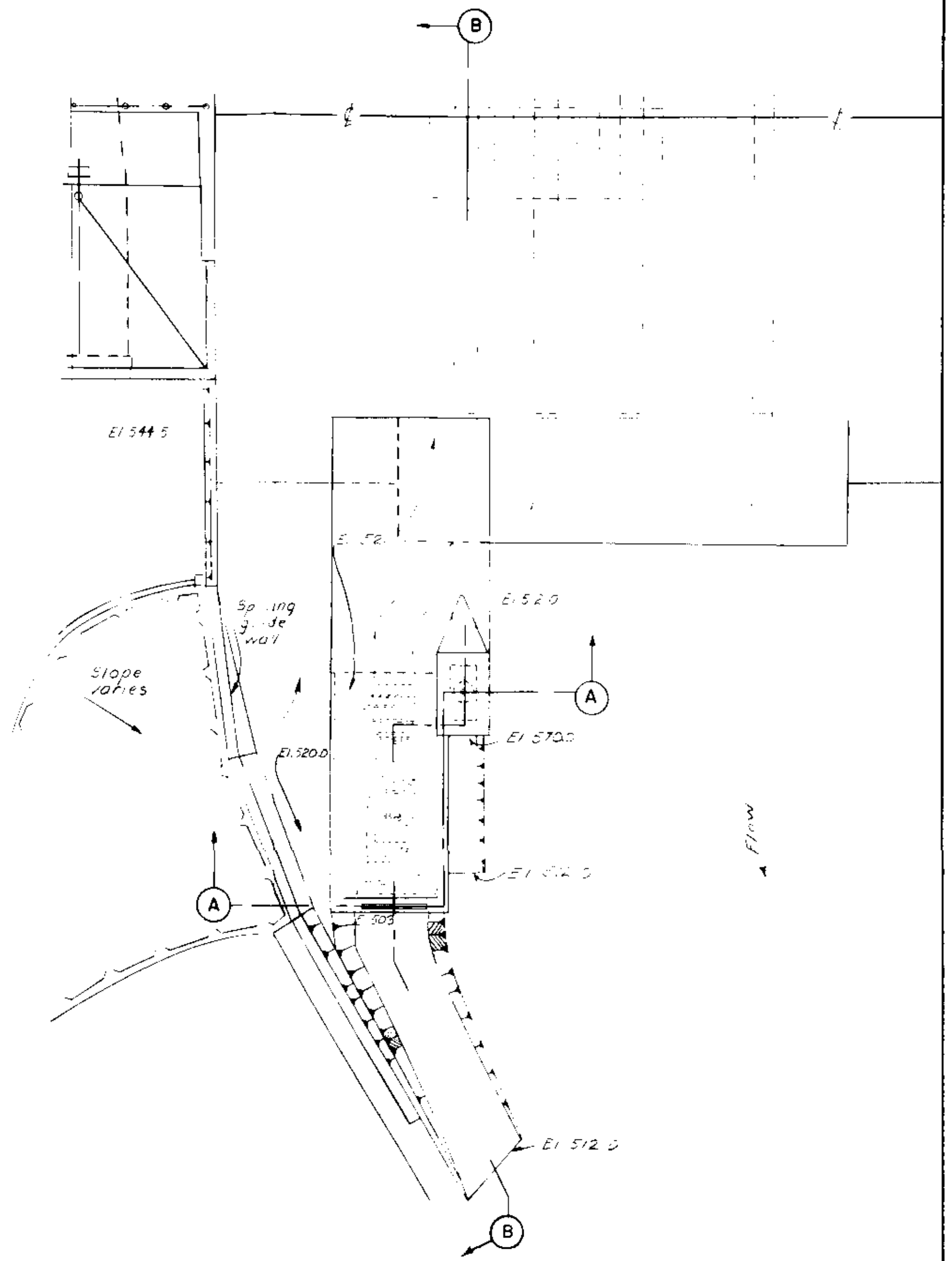
PLATE 8



SECTION A-A



SECTION B-B



PLAN - POWERHOUSE AREA

GRAPHIC SCALE

1" = 10'

10' 0 10' 20'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES INVESTIGATION

MERRIMACK RIVER BASIN

BLACKWATER DAM

ALTERNATIVE 3

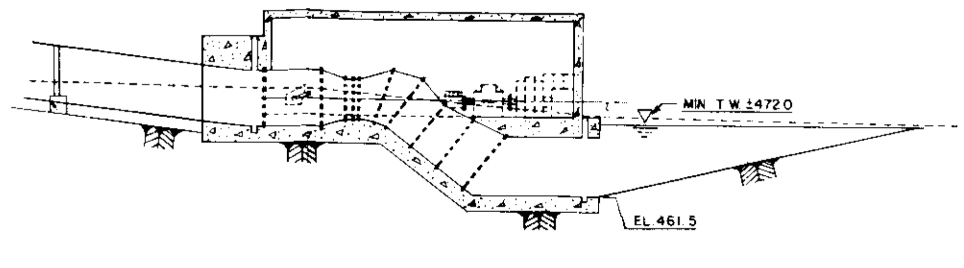
PLAN AND SECTIONS

SCALE: 1" = 10'

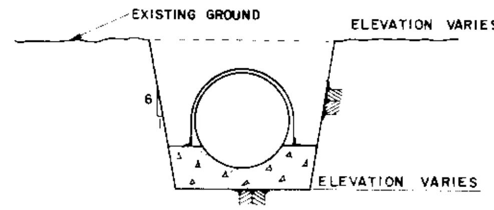
DEC 1985

PLATE 9

PLAN
SCALE: 1" = 100'



SECTION - POWERHOUSE
SCALE: 1" = 10'

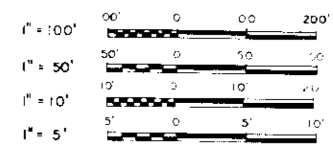


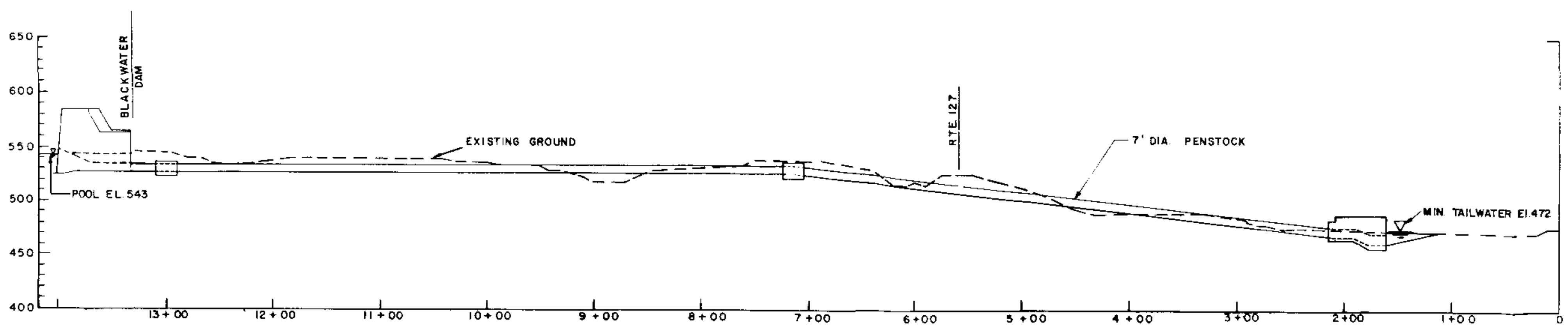
TYPICAL SECTION
PENSTOCK & SUPPORT
SCALE 1" = 5'

NOTES:

1. ALL ELEVATIONS ARE IN FEET ABOVE N.G.V.D.
2. PLAN AND PROFILE BASED ON PHOTOGRAMMETRY OBTAINED IN 1985

GRAPHIC SCALES





PENSTOCK ℄ PROFILE
SCALE: 1" = 50'

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES INVESTIGATION
MERRIMACK RIVER BASIN
BLACKWATER DAM
ALTERNATIVES 4 AND 5
PLAN, PROFILE, SECTIONS

SCALES AS SHOWN | DEC. 1985

PLATE 10

Blackwater Dam Hydropower
Preliminary Feasibility Investigation

APPENDIX A

CORRESPONDENCE

Department of the Army
New England Division, Corps of Engineers
Waltham, Massachusetts

July 1986

United States Department of the Interior

FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
P.O. BOX 1518
CONCORD, NEW HAMPSHIRE 03301

Colonel Carl B. Sciple
Division Engineer
U.S. Army Corps of Engineers
New England Division
424 Trapelo Road
Waltham, Massachusetts 02254

NOV 3 1982

Dear Colonel Sciple:

This Planning Aid Letter is intended to aid your planning efforts for the development of hydroelectric power at the Blackwater Dam Flood Control Project on the Blackwater River in the Towns of Webster and Salisbury, Merrimack County, New Hampshire. It has been prepared under authority of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

We understand that six alternative hydropower development plans are being investigated for the Blackwater project. These alternatives, based on preliminary data received from your staff, are as follows:

Plan 1: Permanent pool of 600 acres at elevation 543 feet National Geodetic Vertical Datum (NGVD). Spillway crest unchanged at elevation 566 NGVD. Run-of-river operation, maximum daily fluctuation of 0.5 feet. Powerhouse at the dam with assumed installed capacity of 300 cfs.

Plan 2: Is similar to Plan 1 except that the powerhouse would be located at the end of a 2,000 or 2,800-foot-long penstock approximately 2,800 feet downstream of the dam.

Plan 3: Permanent pool of over 3,500 acres at elevation 573 feet NGVD. The spillway crest would be raised to elevation 584 NGVD and would increase the existing flood-control pool of 3,280 acres to about 4,580 acres. Peaking operation, maximum daily fluctuation 0.5 feet, estimated maximum drawdown 40 ± feet. A 10,800-foot-long penstock would lead to a powerhouse located approximately 3.66 miles downstream of the dam.

Plan 4: Several different structural modifications resulting in different pool elevations are currently being evaluated. A permanent pool of 1,325 to over 3,500 acres at elevations of 550 to 573 feet NGVD with spillway crest at 568 to 584 feet NGVD. Storage project with powerhouse at the dam, maximum daily fluctuation 0.5 feet, maximum drawdown 10-40 ± feet.

Plan 5: Is similar to Plan 4 except that the powerhouse would be located at the end of a 2,000 or 2,800-foot-long penstock approximately 2,800 feet downstream of the dam.

Plan 6: No permanent pool and no structural modification to dam or spillway. A penstock would lead to a powerhouse located at either 2,800 feet (0.53 miles) or 19,320 feet (3.66 miles) downstream from the dam.

Fish and wildlife resources of the project area have been adequately described in your Reconnaissance Report and, for the most part, need not be repeated in this letter.

Historically, anadromous fish such as Atlantic salmon and American shad ascended the Blackwater River for spawning purposes. The on-going Merrimack River Anadromous Fish Restoration Program will restore anadromous fish to this river. The current timetable envisions such restoration to the base of Blackwater Dam by about 1989, however, fish-passage facilities for this dam have been deferred until the year 2005. Therefore, while fish-passage facilities are not required at this time, the need for such facilities will be critically reviewed in the future.

The Blackwater River is annually stocked with brook, brown and rainbow trout (minimum stocking of 8,700 fish) by the New Hampshire Fish and Game Department. It is considered to be one of the best trout streams in southern New Hampshire and receives heavy fishing pressure.

Wildlife habitat of the project area is considered to be of high quality. The area contains some of the state's finest woodcock and grouse habitat. Much of the excellence of the habitat can be attributed to habitat improvements carried out by the New Hampshire Fish and Game Department including the pruning and release of wild apple trees and the clear-cutting of overmature alder and aspen stands.

Within the project area, the Blackwater River with its many meanders, small backwaters and bordering wooded wetlands provides excellent habitat for waterfowl such as black ducks, wood ducks, hooded mergansers and mallards. In addition, these areas provide good to excellent habitat for furbearers such as beaver, muskrat and mink. During the 1980-81 trapping season, 34 beavers, 37 muskrats, and 4 mink were harvested in this area. 1/

The existing 3,280-acre dry-bed reservoir behind the Blackwater Dam has never been filled to capacity during previous flood control operations. Infrequent flood control operations do adversely impact fish and wildlife resources, but these impacts are short term and not of a severe nature. However, development of hydroelectric power at the Blackwater Dam could have a severe long-term impact upon fish and wildlife resources.

The permanent pools associated with Plans 1 through 5 would inundate from 9 to over 16 miles of the Blackwater River. The loss of this stream habitat would

1/ New Hampshire Fish and Game Department. 1980-81 Trapping Harvest on Army Corps of Engineers Flood Control Areas.

be difficult, if not impossible to mitigate.

Based on available data, it is difficult to predict the type of fishery that would exist in the various power pools. We suspect that at elevation 543 feet NGVD the power pool would predominantly support a warm water fishery and at the higher pool elevations of 550 to 573 feet NGVD a cold water-warm water fishery could be developed. However, the type and magnitude of these potential fisheries needs to be fully investigated. Such investigations should include oxygen and temperature profiles, impacts of reservoir drawdown, and impacts of sport and forage fish being discharged through the turbines.

All of the alternative plans, except Plans 1 and 4, would utilize penstocks connected to a powerhouse to gain operating head and would by-pass from 0.53 to 3.66 miles of stream in the downstream area. Your preliminary plans do not provide for a minimum flow in the by-passed stream area. For planning purposes, we recommend that a minimum flow of 44 cfs be provided in the by-passed stream area. This represents the minimum aquatic base flow as defined by our New England Area Flow Regulation Policy. However, this minimum flow is subject to revision as the downstream impacts of the various hydropower development plans are more fully recognized through further project investigations.

We do not have sufficient information on the operating mode and the range of downstream flows that would occur under Plans 1 through 5 to evaluate downstream impacts. In addition, the impacts of potential dissolved oxygen and temperature changes, fluctuating water levels, and the need for multi-level intakes should be fully investigated with a view toward improving existing conditions in the downstream area so as to partially offset stream losses in the pool area(s).

The permanent pools associated with Plans 1 through 5 would inundate from 600 to over 3,500 acres of wildlife habitat. This loss of wildlife habitat would have to be mitigated. Much of this habitat, especially wetlands, would be difficult to mitigate. Based on our previous experience, utilizing the Service's Habitat Evaluation Procedures (HEP), the mitigation acreage required could range from 3,000 to over 17,500 acres. However, a more definitive mitigation acreage would have to be determined for the various power pools through an actual HEP analysis of the project area.

To put the six alternative hydropower development plans in perspective, they are listed in decending order from the most destructive to the least destructive of fish and wildlife habitat in Table 1.

Table 1. Area of Fish and Wildlife Habitat Impacted by the Alternative Plans

Plan	Stream Area Inundated (Miles)	Stream Area By-Passed (Miles)	Terrestrial Habitat Inundated (Acres)
3	16 +	3.66	3,500 +
5	9-16 +	0.53	1,325-3,500 +
4	9-16 +	0	1,325-3,500 +
2	9	0.53	600
1	9	0	600
6	0	0.53-3.66	0

Of the six alternative plans, Plan 6 would be the least destructive of fish and wildlife resources especially with the shortest penstock route. However, even this plan could be improved upon from a fish and wildlife viewpoint by simply excluding the penstock and constructing the powerhouse at the dam. We recommend that this modification of Plan 6 be included as an alternative to existing project plans.

In order to more accurately assess the impacts of project plans, we will need to develop the following information during the hydropower planning process: (1) an analysis of the power pool areas in relation to dissolved oxygen, temperature and fluctuating water levels, (2) an analysis of the downstream area in relation to dissolved oxygen, temperature, flows, and water level fluctuation, (3) an analysis of multi-level intakes, (4) ascertain the acreage by habitat types that would be impacted by the proposed pools, (5) an analysis of the habitat types utilizing HEP, and (6) an analysis of mitigation lands.

We would be pleased to assist you in the various stages of project planning, and we will report on the potential impacts of your selected plan.

Sincerely yours,

Vernon B Long

Gordon E. Beckett
Supervisor

PSNH

Public Service of New Hampshire

May 13, 1986

Mr. John Kennelly
Department of the Army
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Dear Mr. Kennelly:

The following information is being forwarded in response to our recent telephone conversation. This material should answer some of your questions regarding the interconnection of a small power producer to PSNH's system and current energy purchase rates.

We have prepared a standard review procedure for small energy producers desiring to sell their electrical output to Public Service Company of New Hampshire (PSNH). This procedure is intended to expedite all necessary reviews and negotiations.

Certain general, mechanical, and electrical information is essential in our review of interface requirements. The attached Site Data Sheet is intended to fulfill this need. Please fill out this sheet as completely as possible and return it to this office.

After receiving your completed Site Data Sheet, we will determine the scope of engineering studies, relating to the interconnection of your facility with PSNH's electrical system, that you require from PSNH. If you are in the early stages of your project (determining project economics and/or filing for necessary permits) and the information that you require can be supplied at minimal cost to PSNH, we will initiate the necessary studies and supply the information at no cost to you. If you require detailed engineering studies, we will provide you with a cost estimate for such engineering services. We will require a letter of authorization, accompanied by a minimum prepayment of 50% of the estimated cost, before initiating our studies.

After completing our studies, we will prepare an Interconnection Report for your review. This report will advise you of PSNH's interface requirements, what services are available through PSNH, and cost estimates for the same. Again, as with the PSNH engineering services, we will require a letter of authorization, accompanied by a minimum prepayment of 50% of the estimated cost of all labor and equipment you desire from PSNH, before performing any work.

If, during our review period, your development plans change at all (higher or lower installed capacity, changes in equipment selection, etc.), please notify us as soon as possible and submit a new Site Data Sheet.

859 Central St., P.O. Box 279 • Franklin, NH 03235 • Telephone (603) 934-4010

All questions on metering may be addressed directly to the General Meter Supervisor, Thomas P. Meissner (Extension 2668), and questions on system protection may be addressed directly to the Manager of System Protection and Control Department, Peter A. Magoun (Extension 2536). All other questions should be addressed to me (Extension 2456). We can all be contacted at our General Office in Manchester (603) 669-4000.

All administrative actions and contract negotiations will be performed through our Supplemental Energy Sources Department. Please address all correspondence to my attention.

For your information, copies of our interconnection and metering standards and a policy statement outlining the options available to you are enclosed. The Supplemental Energy Sources Department will assist you, in a timely manner, in coordinating all activities leading to the purchase of energy from your facility.

Very truly yours,

J.E. Lyons

John E. Lyons, P.E.
Director
Supplemental Energy Sources

JEL/dfd

Enclosures:
1 - Site Data Sheet
1 - Interconnection Standards
1 - Acceptable Utility Grade Relays
1 - Metering Standards
1 - Time-of-Use Metering Requirements
1 - Policy Statement

POLICY STATEMENT
CONTRACT PRICING PROVISIONS
LIMITED ELECTRICAL ENERGY PRODUCERS

Public Service Company of New Hampshire (PSNH) will pursue all viable new supplemental energy sources in order to reduce its dependence on foreign oil, delay construction of future baseload power plants for as long as possible, and provide the best possible service to its customers at the lowest reasonable cost. In this pursuit, PSNH will offer Limited Electrical Energy Producers (LEEPS), using wind, non-fossil fuel burning, hydroelectric, or other qualifying generation facilities, located in PSNH or its "wholesale for resale" customers franchised areas and willing to sell their entire output of electric energy, the following contract pricing and term provisions.

PSNH LONG-TERM CONTRACT PROVISIONS

PSNH is willing to negotiate long-term contract rates with Limited Electrical Energy Producers. All negotiated rates will be based on PSNH's Incremental Energy Cost (IEC) which is specifically defined in the following manner.

Public Service's IEC, for any hour, is equivalent to the marginal cost of providing energy for that hour. The marginal cost, for any hour, is the energy cost of the most expensive unit or purchased energy supplying a portion of Public Service's load during that hour and includes all replacement fuel costs, as defined by the New England Power Exchange (NEPEX), for the incremental unit. Replacement fuel costs are the industry-wide (North America) accepted standard for utility interconnection transactions and, in general, include all costs associated with the amount of fuel burned or kilowatthour (kWh) produced. PSNH's IEC will be expressed as a yearly average and will be calculated by averaging all 8,760 hourly incremental energy costs over the calendar year.

PSNH long-term contract payments will be based on IEC's as they actually occur, on a year-to-year basis. The pricing under such a contract shall be based on an IEC as estimated each year by PSNH. When an actual IEC is determined by PSNH, as computed by its Power Supply Department, an adjustment payment by (or adjustment refund to) PSNH will be made to account for any difference between estimated and actual IEC's for that year.

Normally, PSNH would expect to offer rates calculated at 75 percent of IEC. If during negotiations it can be clearly shown that development of a facility will result in specific unusual benefits to PSNH and its customers, rates at higher percentages of IEC may be considered.

PSNH is often asked to consider Contract provisions containing pricing above its IEC for an initial few years of a contract. Such provisions tend to encourage development of facilities earlier than they are needed to meet the Company's load requirements. Due to the impact of such pricing on its customers should particular circumstances indicate consideration of this option, PSNH must be convinced that unusual benefits are inherent in the facility or its location. Unless this can be clearly shown, no serious consideration can be given to such front-end loading. PSNH's consideration will include a review of the plant location, technology, equipment, construction standards to be employed and any other factors that might make the facility particularly beneficial. In evaluating possible benefits PSNH has found that hydroelectric plants, due to their use of a non-cost related renewable resource, comparatively smaller sizes, dispersed locations and other inherent features, tend to offer recognizable benefits. Fuel fired plants however, being proposed in ever increasing sizes, tend to create capacity well in advance of the load growth needed to utilize their output. Hence, benefits resulting from their encouragement are harder to recognize in the near term. In the event that front-end loaded agreements may be justified, all payments above an agreed level, based on PSNH's IEC, must be recovered by PSNH in later contract years considering the present worth of money. Some historical PSNH IEC's are listed below, expressed in cents per kilowatthour (¢/KWH).

1979	3.20 ¢/KWH	1982	5.36
1980	4.62	1983	5.37
1981	5.55	1984	5.30

Attached is a graph of PSNH IEC's, projected through time, as estimated by PSNH during June 1985. These rates are presented for your information only and will not be guaranteed by PSNH.

LEEPA RATES

In accordance with NHRSA 362-A: Limited Electrical Energy Producers Act (LEEPA) and subsequent orders of the New Hampshire Public Utilities Commission (PUC), LEEP's may choose short-term or long-term rates, as established by the PUC.

Short and Long-Term LEEPA Rates include both an "energy" and "capacity" component. The energy component can be based on either an "all hours" rate or "time-of-day" (TOD) rates. The capacity component, expressed in dollars per kilowatt-year, is based on a dependable capacity rating as determined by the PUC and is further adjusted by a "peak reduction factor" (see PUC Report and Order No. 17,104 in DE 83-62, dated July 5, 1984 and subsequent orders of the PUC relating to LEEPs).

LEEP's desiring the Short-Term LEEPA Rates must execute an "Interconnection Agreement" with PSNH. This Agreement includes a twelve (12) month termination provision. Rates are reviewed and reestablished by the PUC every six (6) months. The current Short-Term LEEPA Rates, effective through June 1986, are shown below.

Time-of-Day	Energy Rate	Capacity Rate
All-Hours	5.03 ¢/KWH	42.08 $/KW-YR
*On-Peak	5.89 ¢/KWH	
Off-Peak	4.37 ¢/KWH	

* 7:00 a.m. - 10:00 p.m., Monday through Friday, excluding Holidays. Special TOD metering is required for these rates.

LEEP's desiring a Long-Term LEEPA Rate must also execute an "Interconnection Agreement" with PSNH. All Agreements will provide a procedure for the payment of rates established by the PUC, but will not create separate contractual obligations on the part of PSNH to pay these rates. Long-Term LEEPA Rates are available with terms varying from 5 to 30 years and are based on strict guidelines set by the PUC. For informational purposes, the following table present levelized values of the PUC Ordered Long-Term LEEPA Rates, for obligations of 10, 15, 20, and 30 years, commencing in 1986, 1987, 1988 and 1989 and the corresponding capacity values.

ENERGY - ALL HOURS cents/KWH

Term	1986 Start	1987 Start	1988 Start	1989 Start
10	5.73	6.10	6.74	7.46
15	6.83	7.26	7.94	8.72
20	7.76	8.36	9.21	10.17
30	9.80	10.62	11.68	12.87

CAPACITY $/KW-YR

Term	1986 Start	1987 Start	1988 Start	1989 Start
10*	35.73	38.12	40.68	43.41
15*	59.34	63.33	67.57	72.11
20	85.87	91.62	97.76	104.31
30	96.22	102.67	109.55	116.89

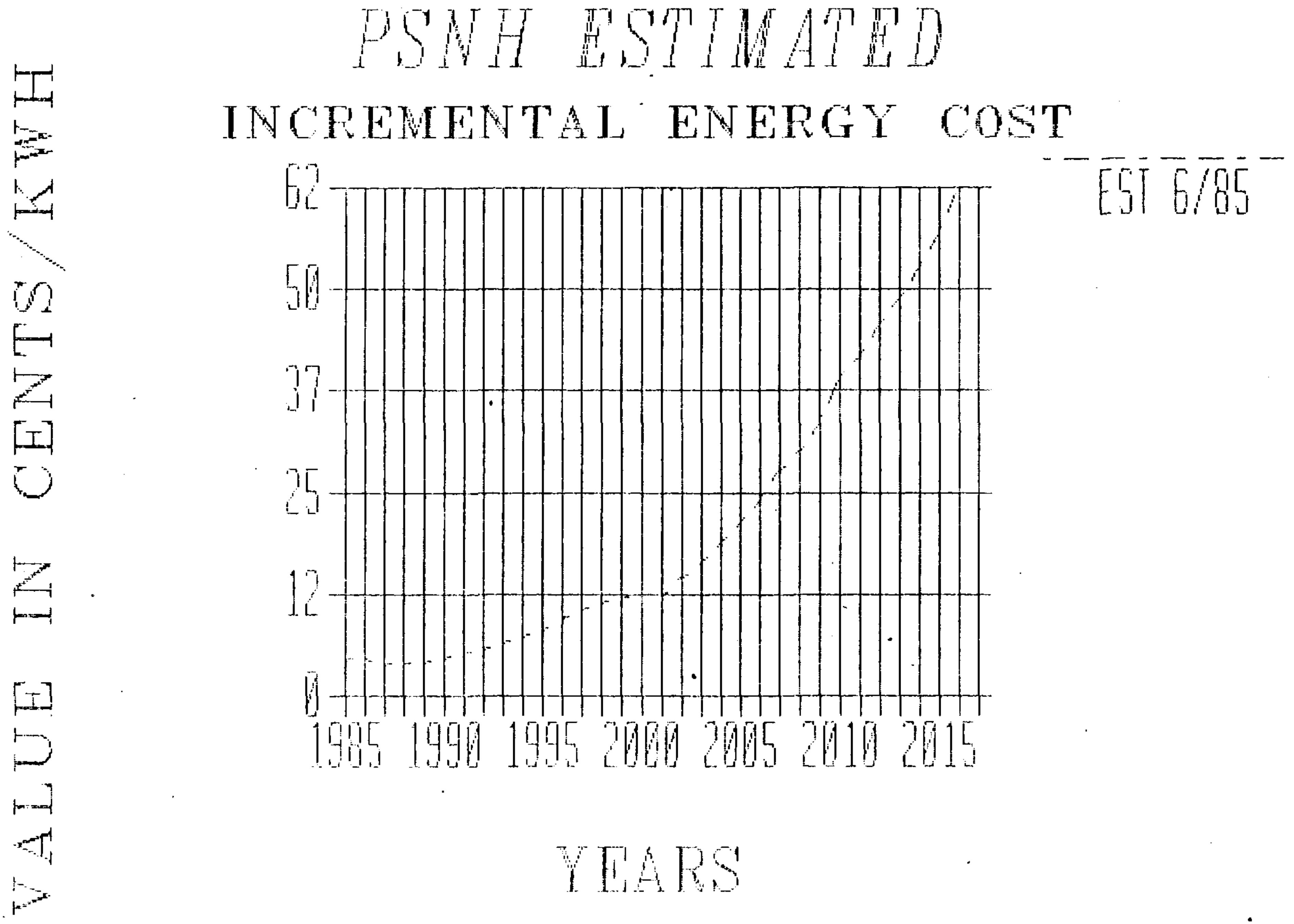
* For rate terms less than twenty (20) years, the above capacity rates are discounted at 5 percent per year, for each year the term is less than twenty.

Pursuant to PUC Order No. 17,104, front-end-loading of the long-term rates is subject to a "ceiling" provision, which must be factored into the rate calculation by developers filing under these rates. Under this provision, the rates for the first three years cannot exceed ninty (90) percent of the levelized rates shown in the above tables.

All questions relating to the Short-Term LEEPA Rate can be directed to PSNH's Supplemental Energy Sources Department. All LEEP's desiring a Long-Term LEEPA Rate must submit a "Long-Term Rate Filing" to the PUC for approval. In either case, the PUC should be contacted to obtain copies of all applicable orders relating to LEEPA Rates.

All LEEP's planning to submit a "Long-Term Rate Filing" to the PUC must initiate interconnection studies with PSNH at least 45 days in advance of such filing. PSNH must be copied on all rate filing correspondence, including subsequent amendments to the filing.

PUBLIC SERVICE COMPANY OF NEW HAMPSHIRE
Supplemental Energy Sources Department
February 18, 1986


PSNH ESTIMATED
INCREMENTAL ENERGY COST
EST 6/85
VALUE IN CENTS/KWH
62
50
37
25
12
0
1985
1990
1995
2000
2005
2010
2015
YEARS

FEDERAL ENERGY REGULATORY COMMISSION
NEW YORK REGIONAL OFFICE
26 FEDERAL PLAZA, ROOM 2207
NEW YORK, NEW YORK 10278

February 27, 1986

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Dear Mr. Ignazio:

In your letter of February 13, 1986, you requested at-market power values for the existing Blackwater Dam flood control project located in Webster, New Hampshire. After subsequent discussions with Mr. John Kennelly of your staff, we estimated the values of hydroelectric power at that site based on contemporary costs and using your recommended Federal interest rate of 8-5/8%. These "snapshot" values are presented in the attached tabulation.

"Snapshot" at-market capacity and energy values represent a summation of the annualized costs associated with the construction, operation and maintenance of the assumed alternative power plant, and the required transmission from its site to the market, at a fixed point in time. The capacity component, $/kW/Yr, reflects mainly the fixed construction costs of the alternative. The energy component, Mills/kWH reflects the variable generation costs of the alternative and consists almost entirely of the cost of fuel consumed.

The market for this calculation was assumed to be the New England Power Pool. At-market power values were estimated for project capacity factors of 10% through 70% in increments of 10%. Alternative power sources considered were peaking oil, cycling coal and baseload coal plants. The costs were based on November, 1985 FERC Form 423 fuel report forms and estimated corresponding Handy-Whitman indices.

For your information, the following FERC dockets for the Blackwater Dam site are presently pending:

Docket No.	Applicant	Status
9313	Great Western Power & Light, Inc.	Preliminary permit application
9325	Merrimack Hydro Assoc.	Preliminary permit application
9868	Essex Hydro Assoc.	Preliminary permit application

If you have any questions, please do not hesitate to contact Mr. Herbert Wolnerman, at (212) 264-1163.

Sincerely,

Martin Inwald
Regional Director

Attachment: Blackwater Flood Control Reservoir Study - At-Market Power Values

Blackwater Flood Control Reservoir Study

(Federal Financing 8-5/8%)

At - Market Power Values

Alternate	Combustion Turbine	Cycling Coal		Baseload Coal			
Plant Factor %	10	20	30	40	50	60	70
November,1985							
Capacity $/kW/YR	50	168	168	263	263	263	263
Energy Mills/kWh	88	27	26	24	23	23	23

TELEPHONE OR VERBAL CONVERSATION RECORD

For use of this form, see AR 340-15; the proponent agency is The Adjutant General's Office.

DATE	24 Feb 86	
SUBJECT OF CONVERSATION	Blackwater Dam Hydropower Study - FERC Energy Values	

INCOMING CALL

PERSON CALLING	ADDRESS	PHONE NUMBER AND EXTENSION
Herb Wolnerman	FERC New York Regional Office 26 Federal Plaza Room 2207 New York, New York 10278	FTS 264-1163
PERSON CALLED	**OFFICE**	**PHONE NUMBER AND EXTENSION**
John Kennelly	NED PL BMB LRPS	647-8255

OUTGOING CALL

PERSON CALLING	OFFICE	PHONE NUMBER AND EXTENSION
PERSON CALLED	**ADDRESS**	**PHONE NUMBER AND EXTENSION**

SUMMARY OF CONVERSATION

Mr. Wolnerman called regarding our request for power values at Blackwater Dam in Webster, New Hampshire. Mr. Wolnerman informed Mr. Kennelly that FERC had undergone an internal reorganization and no longer had the staff to calculate "Life Cycle" and "Displaced Energy". Mr. Wolnerman stated that "Snap Shot" values were the only available energy information.

Mr. Kennelly stressed that "Displaced Energy" values were needed to evaluate the small hydropower developments in New England. Mr. Kennelly asked if the 1984 values provided by FERC could be updated to reflect the current trend in oil prices. Mr. Wolnerman indicated that the data base used to calculate the prior power values was no longer available and that the 1983 oil projections were still the source on record. Mr. Kennelly asked if any information on the methodology used in the calculations was available and was told that it would be difficult to retrieve. Mr. Wolnerman stated that since the energy mix in New England had not changed significantly since 1984 and the oil projections had not changed that the prior projections were still reasonable.

Mr. Kennelly requested that an explanation on why FERC no longer provided "Displaced Energy" values be provided in their letter.

Mr. Wolnerman's supervisor is Mr. Charles Goggins.

FEDERAL ENERGY REGULATORY COMMISSION
NEW YORK REGIONAL OFFICE
26 FEDERAL PLAZA, ROOM 2207
NEW YORK, NEW YORK 10278

August 31, 1984

Mr. Joseph L. Ignazio
Chief, Planning Division
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Mr. Ignazio:

In response to your letter of April 26, 1984, we have determined power values for the Blackwater flood control reservoir. As discussed with Leo Malet of your staff, only at-market power values were calculated. We used annual power factors of 10, 20, 30, 40, 50 60 and 70 percent and a Federal interest rate of 8-3/8%.

Capacity and energy values as of August 1984 (snapshot) were computed based on current fuel prices. Energy values were derived using life cycle cost (LCC) and displaced energy cost (DEC) techniques. The snapshot capacity values may be used in conjunction with the LCC energy values to yield total LCC power benefits. Benefits determined using a DEC methodology do not include a capacity component. Both LCC and DEC energy values use the Department of Energy's energy cost escalation projections prepared by the Energy Information Administration (EIA) in 1984. The regional New England area projections used are derived from the Middle World Oil Price (MIDWOP) forecast scenario in the EIA publication, "Annual Energy Outlook 1983," released in May 1984. Using these projections, fuel cost escalations were derived for the period 1984-2010. After 2010, fuel prices were considered to increase along with the general rate of inflation; i.e., no increase using constant dollars.

It is now staff's policy to consider generation with annual plant factors up to and including 15 percent as the peaking band on utility load curves; plant factors above 15 percent up to and including 30 percent, as the intermediate range; and over 30 percent as baseload. Thermal alternatives employed in evaluating the proposed hydro projects are oil-fired combustion turbines for peaking duty, cycling coal-fired for intermediate operation, and conventional coal-fired units for base load operation. The capital cost of a single 600 MW baseload coal plant is estimated to be $1,620/kW and the heat rate of the baseload coal alternative was taken at 9,500 BTU/kWh. The capital cost of a dual 500 MW cycling coal-fired intermediate plant is estimated at $930/kW and the heat rate was taken at 11,000 BTU/kWh. The capital cost and heat rate for the peaking combustion turbine were taken at $280/kW and 12,500 BTU/kWh. Fuel costs obtained from an August 1984 phone survey of the electric utilities in New England were $2.00, $4.50, and $5.80 per million BTU for coal, residual oil, and number 2 oil, respectively.

The transmission assumed to be necessary to bring the output of the 600 MW baseload coal and 500 MW intermediate cycling coal alternatives to market consists of two single circuit 345 kV transmission lines totaling 100 miles and associated trnasformation, breakers and related equipment. The transmission assumed needed for a combustion turbine consists of a single transmission line loop drop and associated transformation, breakers, and related equipment. The cost of the transmission is included in the at-market alternative's capital cost.

Snapshot at-market capacity and energy values represent a summation of all annualized costs as of August 1984 for constructing and operating a power plant and its required transmission from the thermal site to market. The capacity component in $/kW/Yr reflects the fixed costs associated with the construction and operation of the alternative. The energy or variable component expressed in mills/kWh consists mainly of the cost of fuel consumed.

In the case of LCC values, the snapshot energy values are used as a starting point but are escalated to reflect the increased fuel costs for the 100-year period following the projected hydro project on-line date of 1995. All energy costs were discounted to 1995 to obtain their present worth and then summed. A capital recovery factor was then applied to yield the levelized LCC energy values.

The process for calculating the DEC energy value is essentially similar, but in this case it is the cost of the energy displaced in the six state New England Power Pool (NEPOOL) market area which is escalated. Because of the uncertainty and general lack of information concerning future generating plant additions, the type of generation displaced is assumed to remain constant during the 100-year study period.

The Federal Energy Regulatory Commission has issued a Preliminary Permit (Project No. 7438), to the Hydroelectric Development, Inc. for the

Blackwater Dam and Reservoir.

Estimated at-market power values for the Blackwater Flood Control Reservoir are attached. The capacity values, rounded to the nearest dollar, are applicable to the project's dependable capacity and the energy values, rounded to the nearest mill, are applicable to the average annual generation.

If we can be of further assistance in your study, do not hesitate to contact us.

Sincerely,

Edward T. Tracy

Edward T. Tracy
Regional Engineer

Attachment
As Noted

BLACKWATER FLOOD CONTROL RESERVOIR STUDY

(FEDERAL FINANCING - 8-3/8%)

AT-MARKET POWER VALUES

ALTERNATE	COMBUSTION TURBINE	CYCLING COAL		BASELOAD COAL			
Plant Factor %	10	20	30	40	50	60	70
August 1984							
Capacity $/kW/Yr	40	140	140	239	239	239	239
Energy Mills/kWh	74	18	30	16	21	24	26
Life Cycle Cost							
Energy Mills/kWh	293	28	47	22	30	34	37
Displaced Energy							
Energy Mills/kWh	201	201	187	187	187	187	171

Blackwater Dam Hydropower
Preliminary Feasibility Investigation

APPENDIX B

FLOOD CONTROL STORAGE NEEDS

Department of the Army
New England Division, Corps of Engineers
Waltham, Massachusetts

July 1986

APPENDIX B

BLACKWATER DAM HYDROPOWER STUDY
FLOOD CONTROL STORAGE NEEDS

Section I
FLOOD CONTROL DAMS IN NEW ENGLAND

INTRODUCTION

This appendix presents hydrological information and discussion regarding flood control storage needs at Corps' reservoirs in New England and the relative impacts of any encroachment on available storage for other uses such as hydropower. Section I discusses the overall flood storage requirements for the Corps' projects in New England and Section II addresses the storage requirements at Blackwater Dam, in Webster, New Hampshire.

The accelerating increase in the cost of energy has generated considerable interest in the possible hydropower development at existing Corps of Engineers dams. All Corps dams in New England are principally for flood control. In many instances no head is available for the development of hydropower without either infringing on available flood control storage or raising the dam to provide additional storage. The addition of storage would minimize any impact on flood control and would generally be the Corps preferred plan for hydropower development. However, the cost of raising a dam can be very expensive and may not produce an economically feasible project. The infringement on a small portion of the flood control storage would be the most economical option, but would impact on the operation of the existing project.

EXISTING FLOOD STORAGE PROJECTS

The Corps has constructed 35 dams within the New England Division, with seven projects self-regulating flood control reservoirs and the remainder gate regulated and operated by the Corps. Most of the projects authorized prior to 1955 were for flood control only, whereas, some of the newer projects have other such as recreation, conservation and low flow augmentation. Two projects, namely, Colebrook and Littleville, have significant storage for water supply. No NED reservoir presently has hydropower, though a license has recently been granted by FERC for non-Federal hydropower development at the North Hartland dam and preliminary permits have been granted for feasibility studies at many of the other projects. Basic data on the 28 gage regulated Corps projects in New England is listed in Table 1.

TABLE 1

NEW ENGLAND DIVISION
CORPS OF ENGINEERS
GATE REGULATED FLOOD CONTROL RESERVOIRS
BASIC DATA

Project	Year Completed	Drainage Area	Flood Control Ac-Ft	Flood Control Inches R.O.	Net Head	Normal River Basin
Union Village	1950	126	38,300	5.7	0-30'	Connecticut
North Hartland	1961	220	68,750	5.8	20-35'	"
North Springfield	1960	158	48,500	5.8	15	"
Ball Mountain	1961	172	52,300	5.7	25-65	"
Townshend	1961	106 Net	32,800	5.8	21	"
Surry Mountain	1941	100	31,700	5.9	15	"
Otter Brook	1958	47	17,600	7.0	18-20	"
Birch Hill	1941	175	49,900	5.3	0	"
Tully	1949	50	20,500	7.7	11-16	"
Barre Falls	1958	55	24,000	8.2	0	"
Knightville	1941	162	49,000	5.7	0-25	"
Littleville	1965	52	23,000	8.3	86	"
Colebrook	1969	118	50,200	8.0	67	"
Franklin Falls	1943	1,000	150,000	2.7	0	Merrimack
Edward MacDowell	1950	44	12,800	5.4	6±	"
Hopkinton	1962	382 Net	*	6.8	0	"
Everett	1961	64	*	6.8	15+	"
Blackwater	1941	128	46,000	6.7	0	"
Hodges Village	1959	31	13,250	8.0	0	Thames
Buffumville	1958	26.5	11,300	8.0	11±	"
East Brimfield	1960	67.5	29,900	8.3	13±	"
Westville	1962	32 Net	11,000	6.4	11±	"
West Thompson	1965	74 Net	25,600	6.5	13±	"
Mansfield Hollow	1952	159	49,200	5.8	11-16	"
Thomaston	1960	71 Net	42,000	11.1 Net	0	Naugatuck
Black Rock	1970	20	8,450	7.8	27±	"
Hop Brook	1968	16	6,850	7.8	18±	"
West Hill	1961	28	12,450	8.3	0	Blackstone

*Hopkinton-Everett combined storage 161,600 acre-feet

ASSESSING FLOOD STORAGE NEEDS

The probable maximum 24-hour precipitation for a 200-square mile area in New Engalnd, as established by the National Weather Servic, is about 20 inches. Over 18 inches of rainfall was recorded in a 24-hour period at Westfield, Massachusetts in August 1955, and rainfall exceeded 16 inches at locations in Massachusetts and Connecticut during the period 17-21 September 1983. Hurricane "Edna", which was aimed for New England just before turning west into New York and Pennsylvania, has storm totals of 14 to 18 inches over many areas of those two states. Water equivalent of the spring snowpack often exceeds 10 inches at the higher elevations in New England. It could therefore be rightfully argued that the desirable storage requirement for flood control in New England would be that equivalent to about 20 inches of runoff from the project watershed. However, the desirable is often not practical, physically or economically. Though the Probable Maximum Flood is used for the design of the spillways at the dams it is not used as the criteria for determining flood control storage capacity.

In studies during the design of the New England system of reservoirs it was found that flood control storage capacity equivalent to 6 to 8 inches of runoff from the contributing watershed, was a reasonable amount of storage that should be sought as a general rule where some small degree of risk could be accepted but a high degree of protection was justified to provide security against floods of a disastrous magnitude. This includes the protection against tangible flood losses that may be estimated in monetary terms.

The finally developed storage capacity was often governed by physical limitations at the respective sites or by the overall project economic feasibility, however, with the exception of two projects, one with only 2.7 inches of storage and the other with 11.1 inches, storage capacities of the other 26 projects range from 5.3 to 8.3 inches of runoff with a median of 6.8 inches. It was determined that storage capacities of this order of magnitude provided reasonably good regulating capability, and though uncontrolled spillway discharge would occur at many of the projects in a repeat of record floods such as those of March 1936, September 1938 and August 1955, such spillage would occur during the recession period of the flood generally after the occurrance of peak flows and stages at principal downstream damage centers. Storage capacity equivalent to 6 to 8 inches of runoff would also provide standard project flood regulating capability with spillage limited to the recession period of the flood runoff. The standard project flood is a synthetic flood resulting from a standard project storm under optimum antecedent runoff conditions. It has a 24-hour storm rainfall in New England, for a 200 square mile area, in the order of 10 inches. This flood is used extensively as the criteria for the design of dikes and walls for the protection of human life and property. "The standard project flood is intended as a practicable expression of the degree of protection that should be sought as a general rule in the design of flood control works for comminities where protection of human life and unusually high-value property is involved." (Reference: EM 1110-2-1411). In addition to potential flood volume runoff there are other factors affecting storage capacity needs at specific project sites. Other factors to be considered are:

(1) Drainage Area Controlled - Flood control storage needs are not only a function of the magnitude of flood runoff but also on the amount and duration that flows have to be throttled. If a project is located in close proximity to the downstream damage centers and controls a large percentage of the drainage area, then flows need only to be throttled to safe channel capacity for the duration of excess inflow and subsequent storage emptying. However, if the project controls only a fraction of the watershed above the damage centers, to obtain effectiveness, the flood control gates must be operated early to allow for downstream travel time and must be shut down completely for the duration of flood producing runoff from the uncontrolled area, thereby utilizing proportionally greater amounts of storage. Most projects in New England are located in the headwaters of watersheds, thus falling into the latter category with respect to controlled drainage area. Some damage center watersheds contain more than one reservoir. As reservoirs are added in a basin it lessens somewhat the pressures on flood storage utilization at the older projects. For example, the Knightville project in the Westfield basin is a project with less than average flood control storage capacity, and has twice been filled to capacity. Though its capacity is still limited, the later construction of Littleville Dam in the basin of the Middle Branch eased somewhat storage utilization pressures on the older Knightville project.

(2) Channel Capacity - Non-damaging channel capacity at the downstream principal damage centers greatly influence the amount and duration of required reservoir flood control storage needs. The relative channel capacity determines the time of initial gate closure, duration of restrictive channel capacity, due to channel construction, flood plain developments or agricultural concerns, increased flood storage utilization and also the additional emptying time adds to the chance of a secondary storm development before post-flood control storage emptying is complete. The Surry Mountain project on the Ashuelot River upstream of Keene, New Hampshire is an example of a project with very low downstream channel capacity, due to flat stream gradient and flood plain developments, resulting in frequent, sizable and long duration storage utilization.

The limited channel capacity can also require flow throttling over relatively long periods of time during snowmelt runoff, resulting in appreciable flood storage utilization.

(3) Flood-Series - In considering flood storage needs, one must regard the possibility or probability of a secondary flood runoff occurring before initial flood storage is emptied. The longer the duration of required storage utilization, the greater the probability of secondary

flood runoff. The March 1936 flood was the result of two storm events approximately a week apart. The storage requirement for this two-peaked flood event at many projects, even though there would have been some releases made from storage between the two flood peaks.

(4) Flood Development - Downstream flood development is another factor affecting flood storage needs at a project site. A project on a lower basin tributary, such as the Westfield River in the Connecticut basin, might throttle flows initially to control flooding in the tributary but then have to remain throttled until the main stem peak has passed. Thus the duration of flood regulation is extended and storage utilization increased due to the timing of downstream flood development.

Emptying storage at upper basin projects can also be hampered when there is considerable travel time between the project and lower basin damage centers and weather conditions indicate any possibility of a secondary storm development over the intervening watershed area. This is quite often the condition when regulation for long duration snowmelt at upper basin projects with release rates governed to some extent by uncertain weather conditions and the possibility of a significant rainfall over the downstream uncontrolled drainage area.

DESIGN LIMITATIONS

Analyzing historic and synthetic flood events, with assumed project operation, provide valuable information for establishing storage capacity needs. However, analyzing project operation in hindsight often results in overly optimistic storage capacity needs. When analyzing project operation in hindsight, the exact volume, timing, and duration of the flood is known, therefore, optimum project operation is assured. In actual operation, one does not know in advance what the magnitude, timing and duration of the flood event will be and must operate judiciously for varying possible flood development eventualities. When operating a project during a storm, often at night with a minimum of hydrologic data and forecast information, one is required to operate conservatively. In actual operation projects are usually throttled earlier and reopened later that in modeled project operation. Thus actual storage capacity needs are normally greater than theoretical storage capacity based on flood analysis by hindsight. As appropriately stated in EM 1110-2-3600: "Inadequate flood control storage capacity has resulted when too strict adherence was made to the results of mathematical determinations of the most economical storage capacity without provision of a factor of safety for the difference between actual operating conditions and paper deductions."

The selection and sizing of water resource systems are customarily based on the maximization of net economic benefits. This approach is also of value in the process of selecting the most appropriate flood control capacity; however, it should not be the only or necessarily the governing criteria in final storage selection. Unusually large floods, or series of floods, occur infrequently and require much more reservoir capacity than the smaller more frequent floods. An economic analysis might indicate that the greatest benefit cost ratio would be realized by designing only for the lesser more frequent event and accepting the consequences of a major event. Such practice is not appropriate in the design of flood control projects where a high degree of protection is justified by hazards to life and property. Most flood control reservoirs were authorized by Congress as a result of a major flood experience. Building a project with insufficient capacity to store floods at least as great as those experienced in the region would be unwise and could result in advancing a dangerous false sense of security in downstream areas. In summary, if a high degree of flood control is the intended purpose of the project, then adequate storage capacity must be provided even though the cost of the last incremental storage may be equal to, or even somewhat greater, than the computed incremental flood control benefit. For this same reason it would be foolhardy to evaluate incremental encroachment of storage capacity for other uses, as some have suggested, by incrementally evaluating benefits gained versus incremental flood control benefits lost. Any such exercise would likely show economic justification for significant encroachment on capacity at the detriment of the congressionally authorized purpose of the project.

The fallacy of operating only for the more frequent minor floods was previously discussed. Pitfalls of another sort can be encountered when operating for major floods only. When project operation procedures are developed through analysis of a project design flood, regulated releases are often specified so that storage is just utilized under design flood conditions. Such specified release rates may result in considerable loss of flood control benefits and public disapproval during the more frequent minor floods. Where storage capacity is limited, relatively high regulated releases may be required; however, compromise operating procedures are usually developed which will provide reasonably effective control of major floods while at the same time provide some control during the smaller more frequent flood events.

The determination of the storage requirements for a particular project is based on empirical interpretation of historical data using standard mathematical methods. The accuracy of the predicted flood control requirements can only be determined by long term operational experience. The 28 projects in New England have been operated for various periods of time ranging from 12 to 40 years. One project, Knightville, has been filled to spillway crest twice in its 40-year history. Three projects have been filled to over 80 percent and 12 reservoirs have been filled to over 60 percent of flood storage capacity. The percent of storage utilization at the respective projects has of course varied with relative storage capacity, severity of storm exposure during the period of operation due to other previously discussed factors affecting storage requirements. Peak storage utilization at the projects through July 1982 are listed in Table 2. It is noted that peak storage at 19 of the 28 projects occurred in the months of March and April, illustrating the effect of snowmelt of flood storage requirements in New England.

TABLE 2

NEW ENGLAND DIVISION RESERVOIRS
EXPERIENCED FLOOD CONTROL STORAGE UTILIZATION

Project	Placed in Operation	Percent Filled	Date
Union Village	1950	53	Apr 69
North Hartland	1961	63	Apr 69
North Springfield	1960	69	Apr 69
Ball Mountain	1961	82	Apr 69
Townshend	1961	70	Feb 81
Surry Mountain	1941	89	Jun 84
Otter Brook	1958	82	Jun 84
Birch Hill	1941	64	Jun 84
Tully	1949	61	Jun 84
Barre Falls	1958	64	Jun 84
Knightville	1941	100	Jun 84
Littleville	1965	83	Jun 84
Colebrook	1969	90	Jun 84
Franklin Falls	1943	76	Mar 53
Edward MacDowell	1950	85	Jun 84
Hopkinton	1962	59	Jun 84
Everett	1961	59	Jun 84
Blackwater	1941	74	Apr 69
Hodges Village	1959	44	Mar 68
Buffumville	1958	43	Mar 68
East Brimfield	1960	47	Jun 84
Westville	1962	56	Jun 84
West Thompson	1965	53	Jun 84
Mansfield Hollow	1952	66	Jun 84
Thomaston	1960	50	Jun 84
Black Rock	1970	65	Jun 84
Hop Brook	1968	53	Jun 82
West Hill	1961	59	Mar 68

Estimated limits of significant encroachment of flood control storage was developed for each of the Corps' dams in New England. These limits of significant encroachment were developed based on operational experience at each project and were done independent of any analytical modeling procedure. No encroachment was considered permissible at three projects: Franklin Falls, Surry Mountain and Birch Hill. Surry Mountain was ruled out due to the limited downstream channel capacity through Keene, New Hampshire. The other two were ruled out mainly because of their limited storage capacity. The amount of encroachment varied between the remaining projects primarily with the total storage capacity. A listing of the relative storage needs at each project is listed on Table 3. This analysis is intended as a general level of encroachment when initiating more indepth studies. Individual projects would require detailed hydrologic analysis to determined the allowable encroachment on the flood control storage. A plot of encroachment versus storage capacity for each project is shown on Plate 1.

TABLE 3

NEW ENGLAND DIVISION RESERVOIRS
ESTIMATED LIMIT OF NONSIGNIFICANT
ENCROACHMENT ON FLOOD CONTROL STORAGE

Project	Existing Storage (Inches R.O.)	Encroachment (Inches R.O.)	Remaining F.C. Storage (Inches R.O.)
Union Village	5.7	0.1	5.6
North Hartland	5.8	0.2	5.6
North Springfield	5.8	0.2	5.6
Ball Mountain	5.7	0.1	5.6
Townshend	5.8	0.1	5.7
Surry Mountain	5.9	0	5.9
Otter Brook	7.0	0.5	6.5
Birch Hill	5.3	0	5.3
Tully	7.7	0.7	7.0
Barre Falls	8.2	2.1	6.1
Knightville	5.7	0.3	5.4
Littleville	8.3	1.2	7.1
Colebrook	8.0	1.0	7.0
Franklin Falls	2.7	0	2.7
Edward MacDowell	5.4	0.15	5.35
Hopkinton	6.8	0.4	6.4
Everett	6.8	0.4	6.4
Blackwater	6.7	0.7	6.0
Hodges Village	8.0	1.0	7.0
Buffumville	8.0	1.0	7.0
East Brimfield	8.3	1.2	7.1
Westville	6.4	0.2	6.2
West Thompson	6.5	0.3	6.2
Mansfield Hollow	5.8	0.1	5.7
Thomaston	11.1 Net	1.6	9.5
Black Rock	7.8	1.0	6.8
Hop Brook	7.8	1.0	6.8

SECTION II
BLACKWATER DAM

GENERAL

Blackwater Dam is located in the Merrimack River basin on the Blackwater River, about 8.6 miles above its confluence with the Contoocook River, in the town of Webster, Merrimack County, New Hampshire, has been in operation since 1941. Blackwater is a single purpose flood control project operated to reduce floods on the Blackwater and Contoocook River and in concert with other reservoirs to reduce floods on the main stem Merrimack River. The city of Concord is the first major downstream damage center of the main stem Merrimack River. The project has 128 square miles of drainage area and a total authorized flood control storage capacity at spillway crest of 46,000 acre-feet, equivalent to 6.7 inches of runoff from its contributing watershed.

MARCH 1936 FLOOD ANALYSIS

An analysis of the March 1936 record flood indicates that the Blackwater project would have filled and with some spillway discharge. The 1936 flood was the result of two high flows about a week apart with only partial storage retrieval between events. Spillway discharge would have taken place during the recession of the second event and it is noted that spillage would have occurred at the time of the modified floodpeak at Concord. Therefore, any loss of storage that would have increased the spillage would have added directly to the modified peak discharge at Concord. An analysis of the March 1936 flood is illustrated on Plates 2 and 3.

The 1936 flood was routed through Blackwater assuming various amounts of storage encroachment. A relationship between storage capacity and 1936 spillage rate is graphically illustrated on Plate 4.

STANDARD PROJECT FLOOD ANALYSIS

A standard project flood inflow was also developed and routed through the project with various amounts of available storage. The standard project flood at Blackwater had a 24-hour storm rainfall excess of 8.6 inches. The standard project flood analysis and the relation between storage capacity and rate of spillage is shown on Plate 5.

It was determined with both the 1936 and SPF analysis that reducing the storage capacity by 0.7 inch from 6.7 to 6.0 inches, or 10 percent, resulted in approximately a 4 to 6 percent reduction in the amount of flood peak modification. A 5 percent reduction in the SPF flood peak modification was considered the upper limit of encroachment without "significant" effect on the authroized purpose of the project.

STORAGE FREQUENCY

The Blackwater project has been operational since 1941. Peak storage utilization occurred in April 1969 when the authorized flood control storage was 76 percent filled. A storage frequency curve, shown on plate 6, was developed from the array of peak storages over the 40 years of project operation. The data was plotted using "Weibull" plotting positions and a curve was fitted to the data. The data was comparatively plotted for the 40 years of record and also with the 1936 computed storage elevation added in an assumed 45-year array. The developed curve indicated a 4 percent annual chance of 70 percent fillage and about a 2.5 percent chance of complete fillage to spillway crest. The chance of fillage would increase to an estimated 3 percent with 0.7 inch encroachment of flood control storage.

HIGH FLOW DURATION FREQUENCIES

High flow duration curves for the Blackwater River at the dam site, developed from period of record flow data prior to construction of the project, are shown on Plate 7. In comparing the high flow duration curves with the developed storage frequency curve, it is noted that storage utilization relative to flow duration days increases with rarity of event, ranging from a 2-day equivalent flow at the 10-year frequency to the 7-day equivalent at the 50-year frequency. The high flow duration analysis was not used as a basis for any conclusions and is presented for informational use only. The relationship between high flow duration and storage utilization would likely vary at projects depending on the degree of flow restriction and duration of operation generally required at the respective projects.

SUMMARY

Based on the general assessment of the flood storage needs at Corps reservoirs in New England and more specifically those at the Blackwater project, is was concluded that 4,800 care-feet (0.7 inch runoff) or about 10 percent of total storage would be the upper limit of encroachment on flood storage without "significant" effect on the authorized purpose of the project, i.e., flood control. It is recommended that this storage encroachment be considered that upper limit in any further feasibility studies not involving provisions for added storage. Establishing costs for the use of such storage, reservoir clearing requirements, operational restraints, as well as any social or environmental concerns would have to be a part of any detailed planning studies.

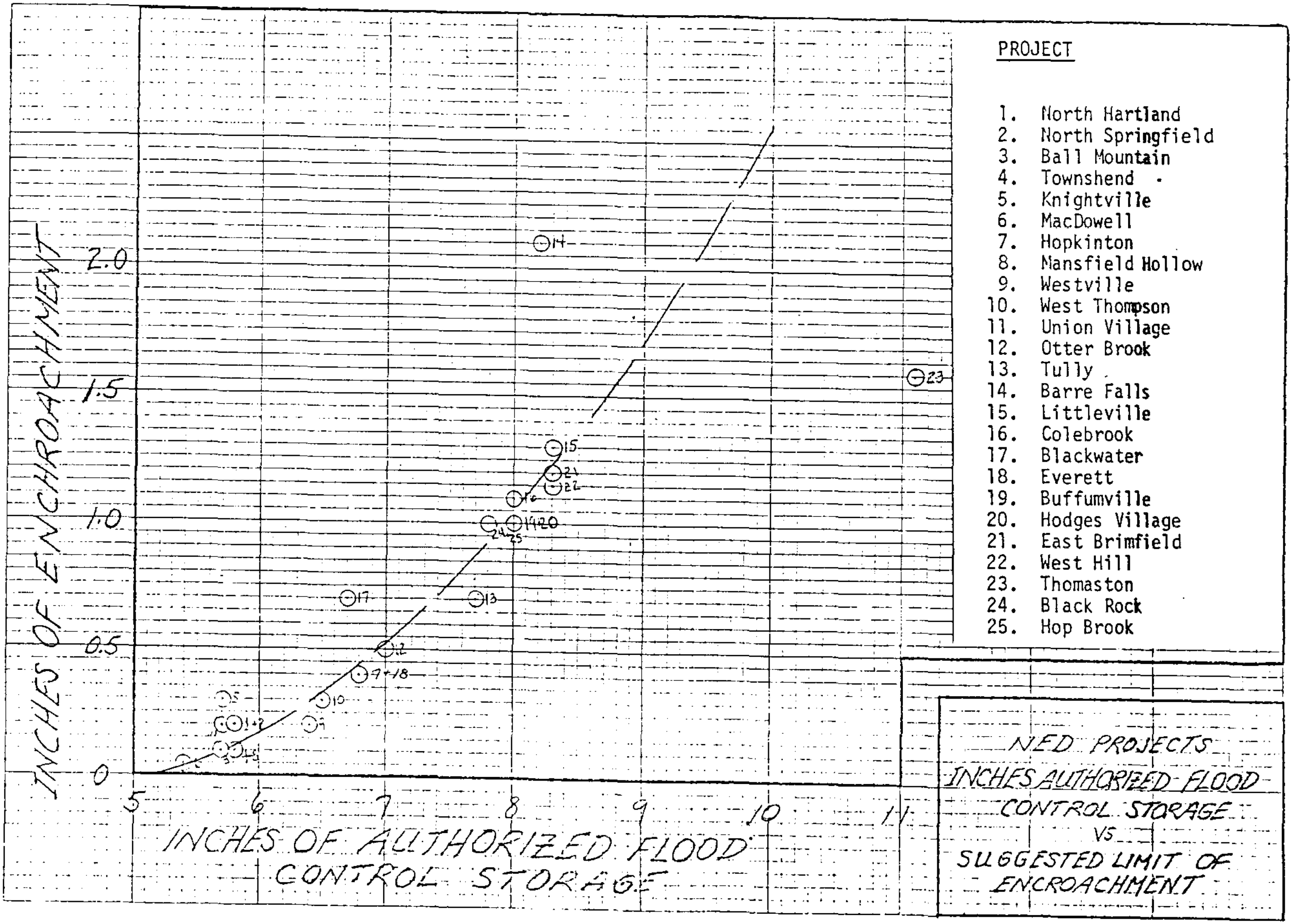
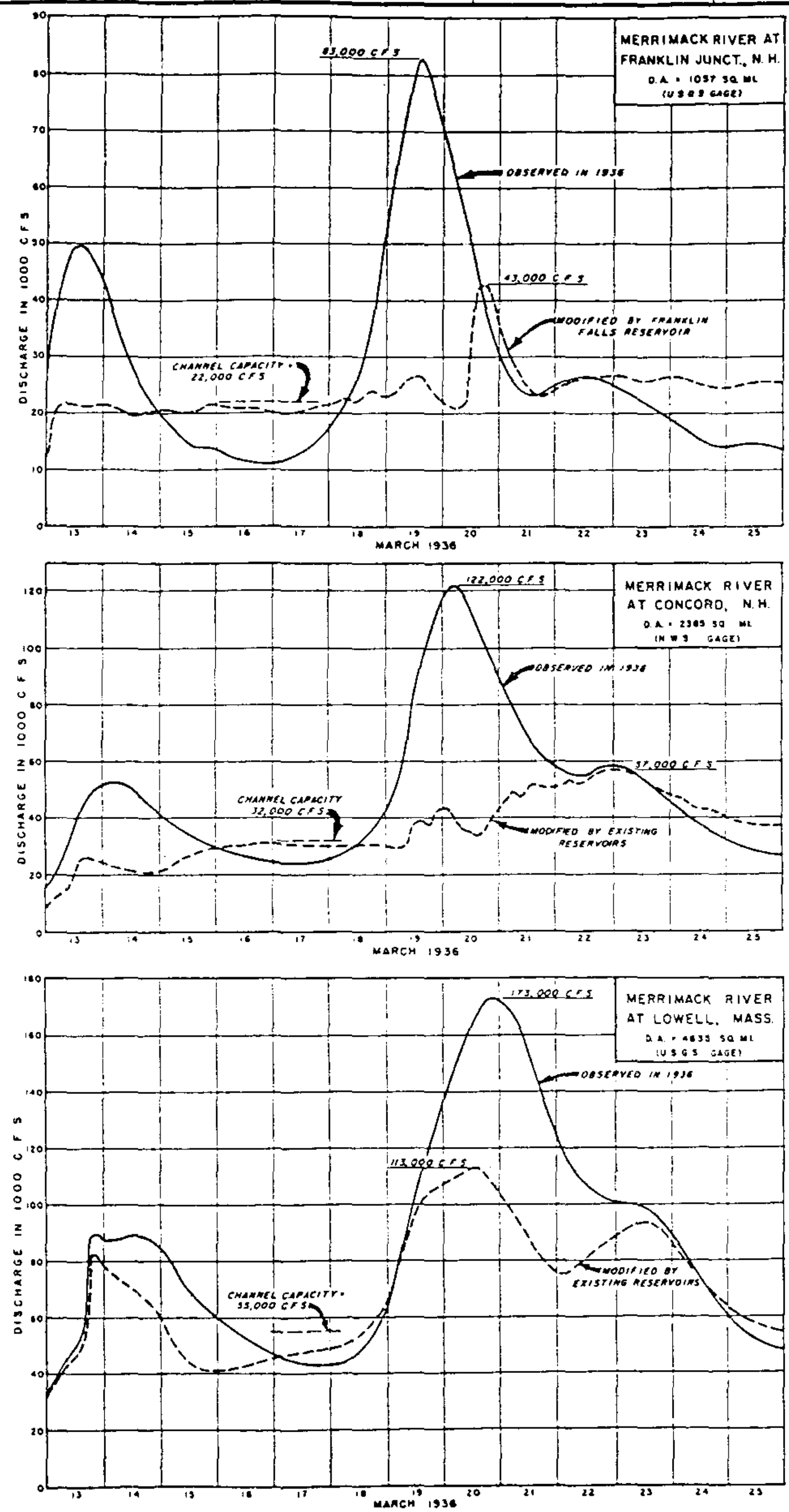
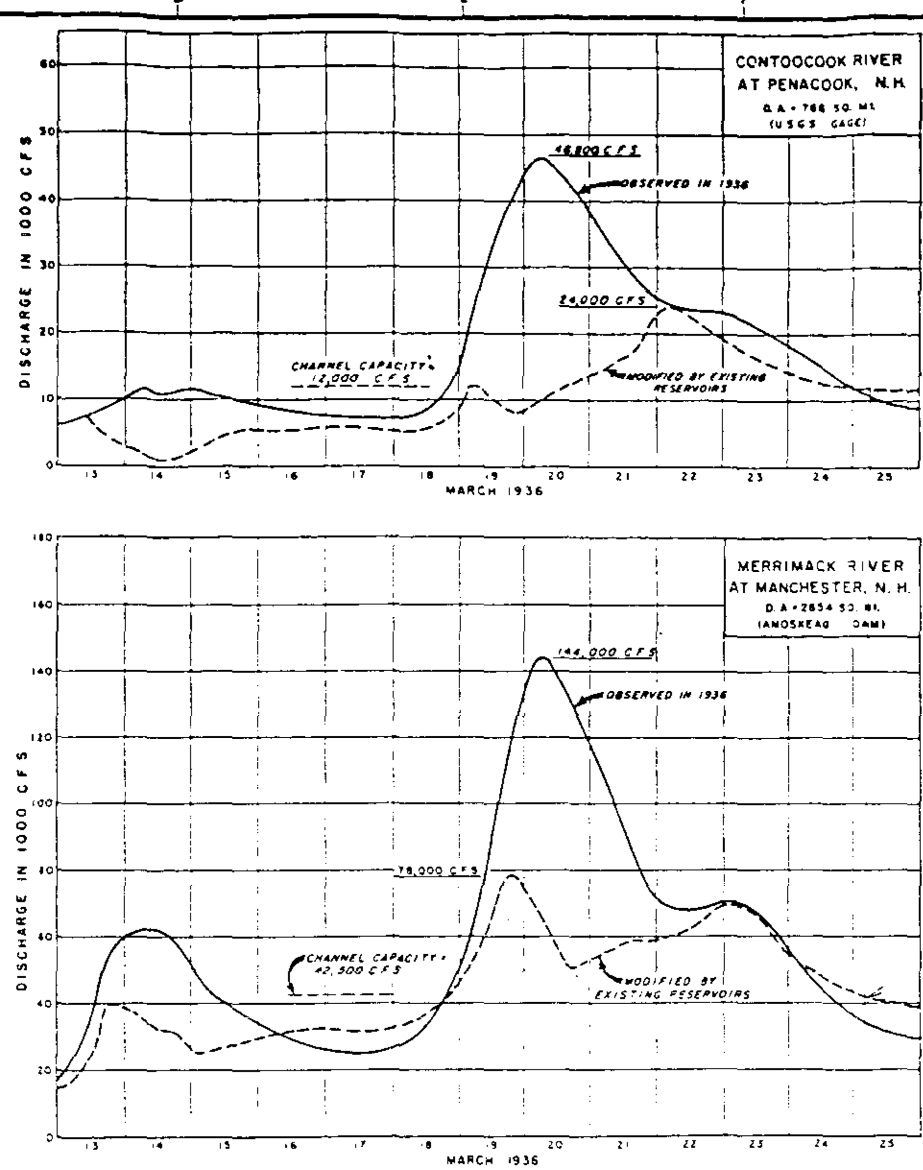
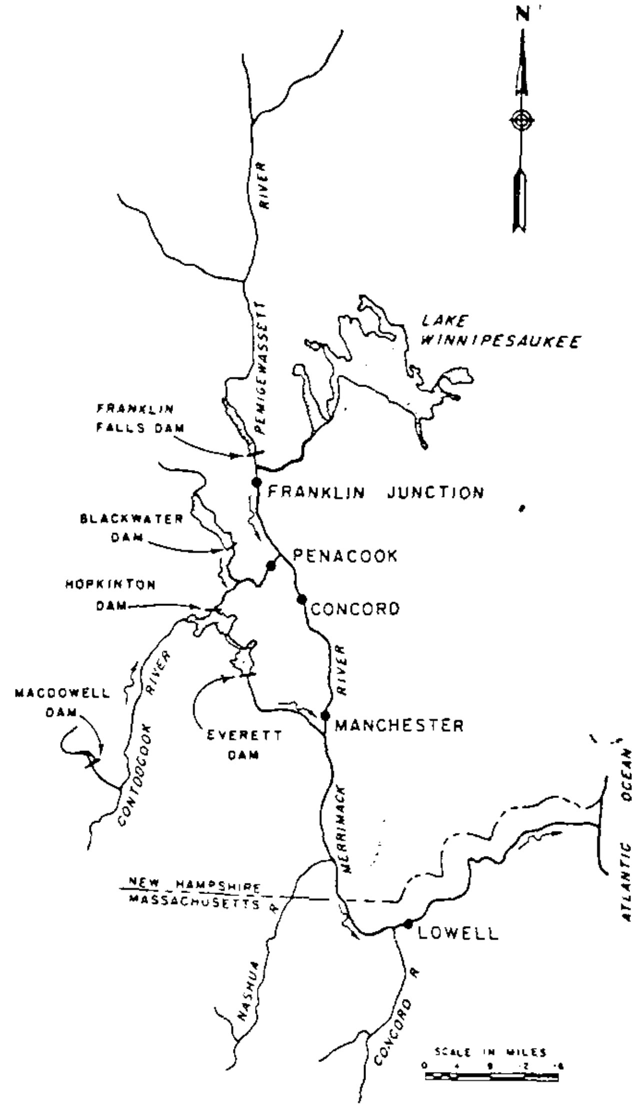

INCHES OF ENCHROACHMENT
0
0.5
1.0
1.5
2.0
5
6
7
8
9
10
11
INCHES OF AUTHORIZED FLOOD CONTROL STORAGE
PROJECT
1. North Hartland
2. North Springfield
3. Ball Mountain
4. Townshend
5. Knightville
6. MacDowell
7. Hopkinton
8. Mansfield Hollow
9. Westville
10. West Thompson
11. Union Village
12. Otter Brook
13. Tully
14. Barre Falls
15. Littleville
16. Colebrook
17. Blackwater
18. Everett
19. Buffumville
20. Hodges Village
21. East Brimfield
22. West Hill
23. Thomaston
24. Black Rock
25. Hop Brook
NED PROJECTS
INCHES AUTHORIZED FLOOD CONTROL STORAGE
VS
SUGGESTED LIMIT OF ENCROACHMENT

PLATE I

CORPS OF ENGINEERS — U. S. ARMY



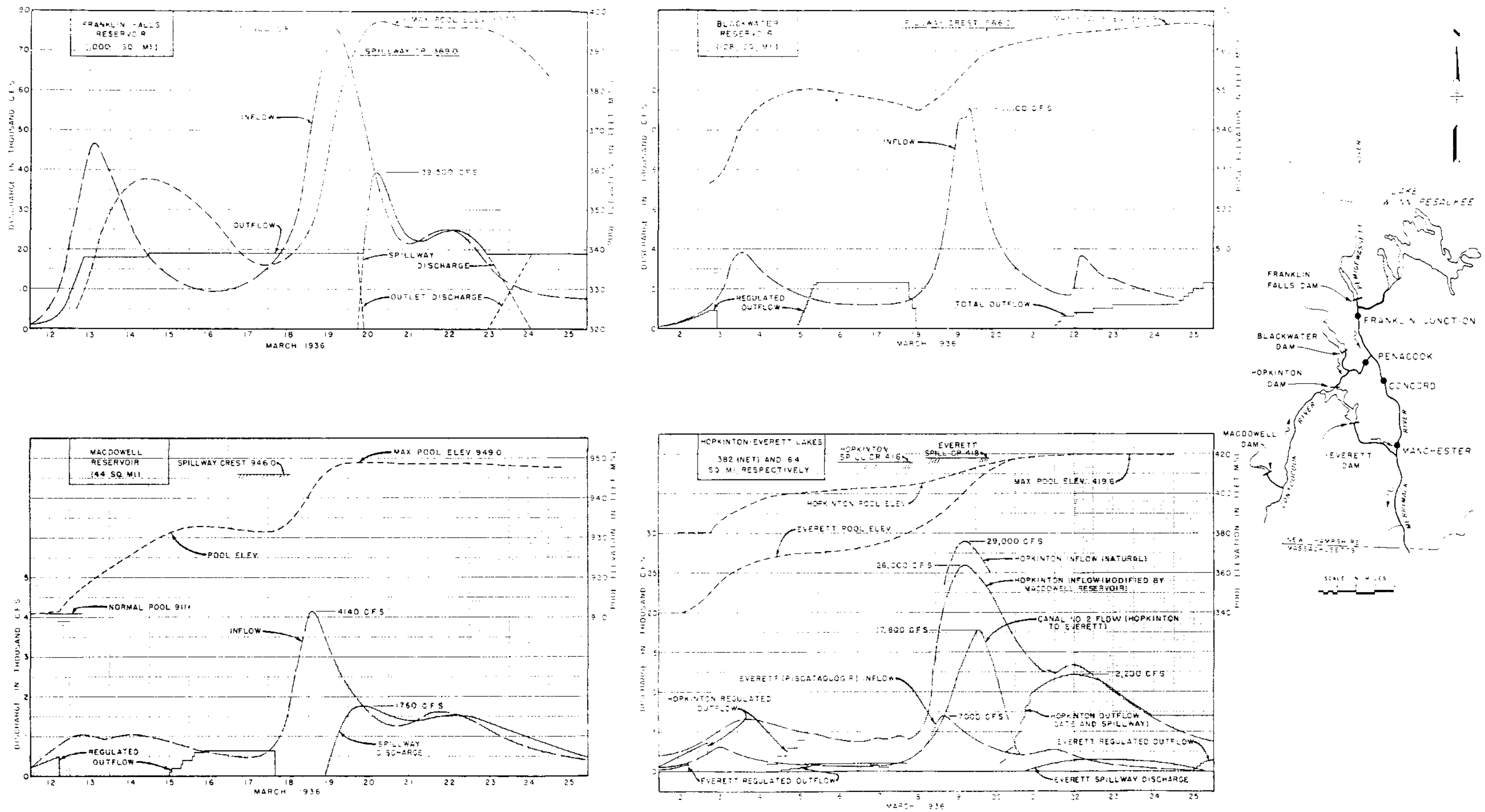




NOTES:
Existing Reservoirs consist of Franklin Falls Reservoir, Blackwater Reservoir, Edward MacDowell Reservoir and Hopkinton-Everett Lakes.
Does not include effects of Soil Conservation Service Projects (Re Chapt 2)

WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN
EFFECT OF REGULATION
MARCH 1936 FLOOD
NEW ENGLAND DIVISION WALTHAM, MASS.
DECEMBER 1978

PLATE 2



WATER RESOURCES DEVELOPMENT PROJECT

MERRIMACK RIVER BASIN

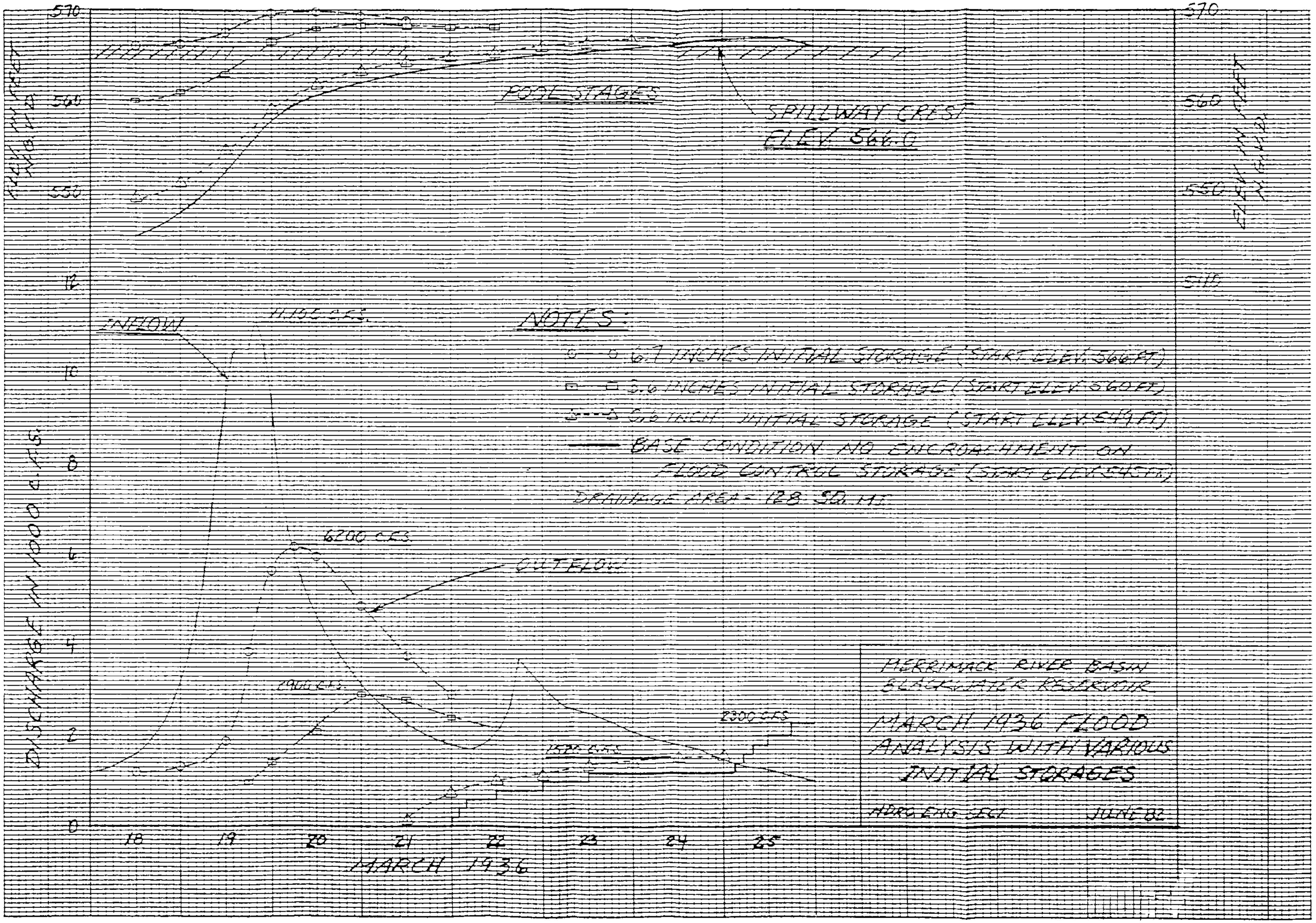
NED RESERVOIRS

EFFECT OF MARCH, 1936 FLOOD

NEW ENGLAND DIVISION WALTHAM, MASS.

DECEMBER 1976

PLATE 3



POOL STAGES
SPILLWAY CREST
ELEV. 566.0
ELEV. IN FEET M.S.L.
INFLOW
11,150 C.F.S.
NOTES:
6.7 INCHES INITIAL STORAGE (START ELEV. 566 FT)
3.6 INCHES INITIAL STORAGE (START ELEV. 560 FT)
0.5 INCH INITIAL STORAGE (START ELEV. 549 FT)
BASE CONDITION NO ENCROACHMENT ON FLOOD CONTROL STORAGE (START ELEV. 545 FT)
DRAINAGE AREA = 128 SQ. MI.
6200 C.F.S.
OUTFLOW
2900 C.F.S.
1500 C.F.S.
2300 C.F.S.
DISCHARGE IN 1000 C.F.S.
MARCH 1936
MERRIMACK RIVER BASIN
BLACKWATER RESERVOIR
MARCH 1936 FLOOD ANALYSIS WITH VARIOUS INITIAL STORAGES
HYDRO. ENG. SECT.
JUNE 82

PLATE 4

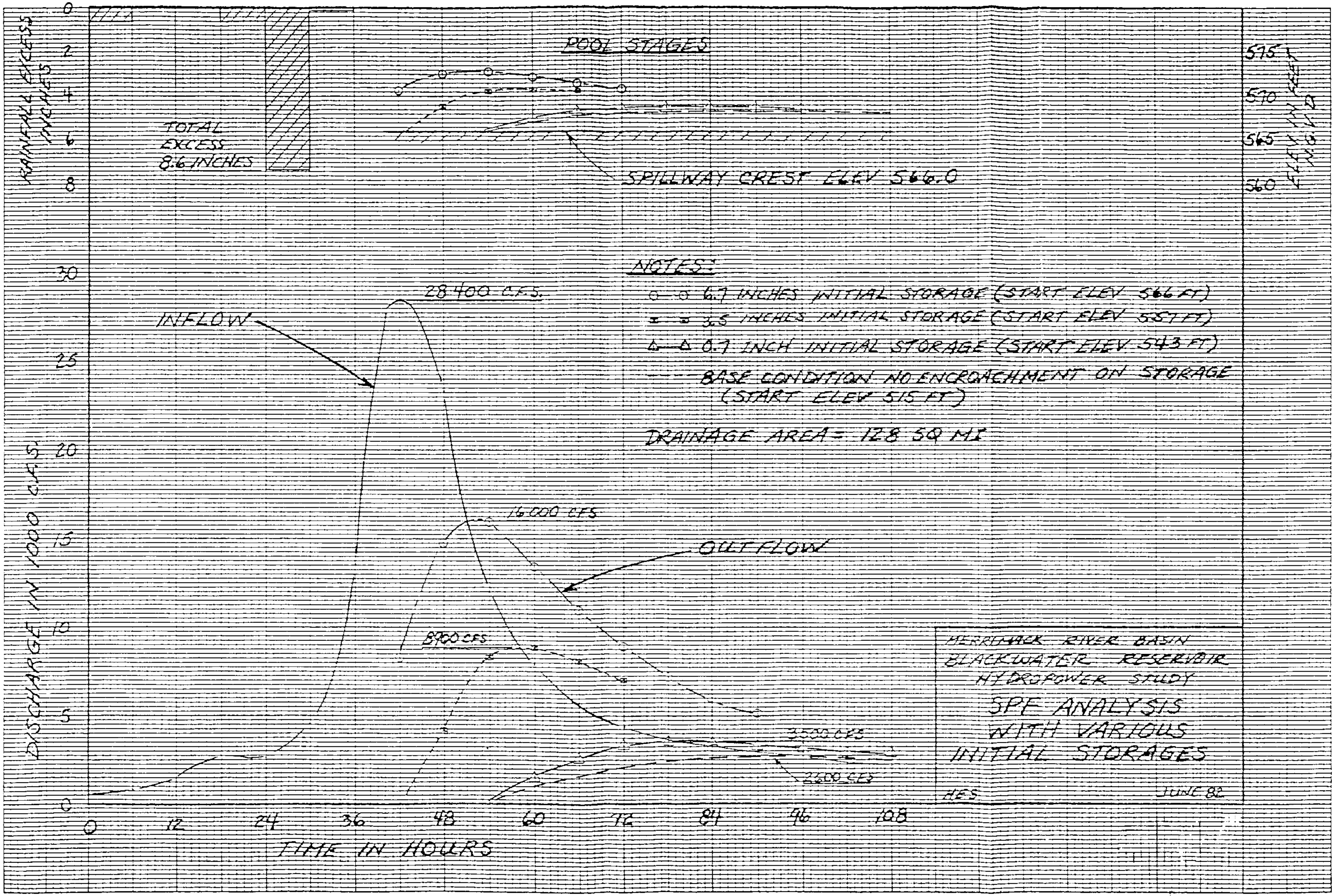

POOL STAGES
TOTAL EXCESS 8.6 INCHES
SPILLWAY CREST ELEV 566.0
RAINFALL EXCESS INCHES
ELEV IN FEET
NOTES:
6.7 INCHES INITIAL STORAGE (START ELEV 566 FT)
3.5 INCHES INITIAL STORAGE (START ELEV 557 FT)
0.7 INCH INITIAL STORAGE (START ELEV 543 FT)
BASE CONDITION NO ENCROACHMENT ON STORAGE (START ELEV 515 FT)
DRAINAGE AREA = 128 SQ MI
28 400 C.F.S.
INFLOW
16 000 CFS
OUTFLOW
8900 CFS
3500 CFS
2600 CFS
DISCHARGE IN 1000 CFS
TIME IN HOURS
MERRIMACK RIVER BASIN
BLACKWATER RESERVOIR
HYDROPOWER STUDY
SPF ANALYSIS
WITH VARIOUS
INITIAL STORAGES
HES
JUNE 82

PLATE 5

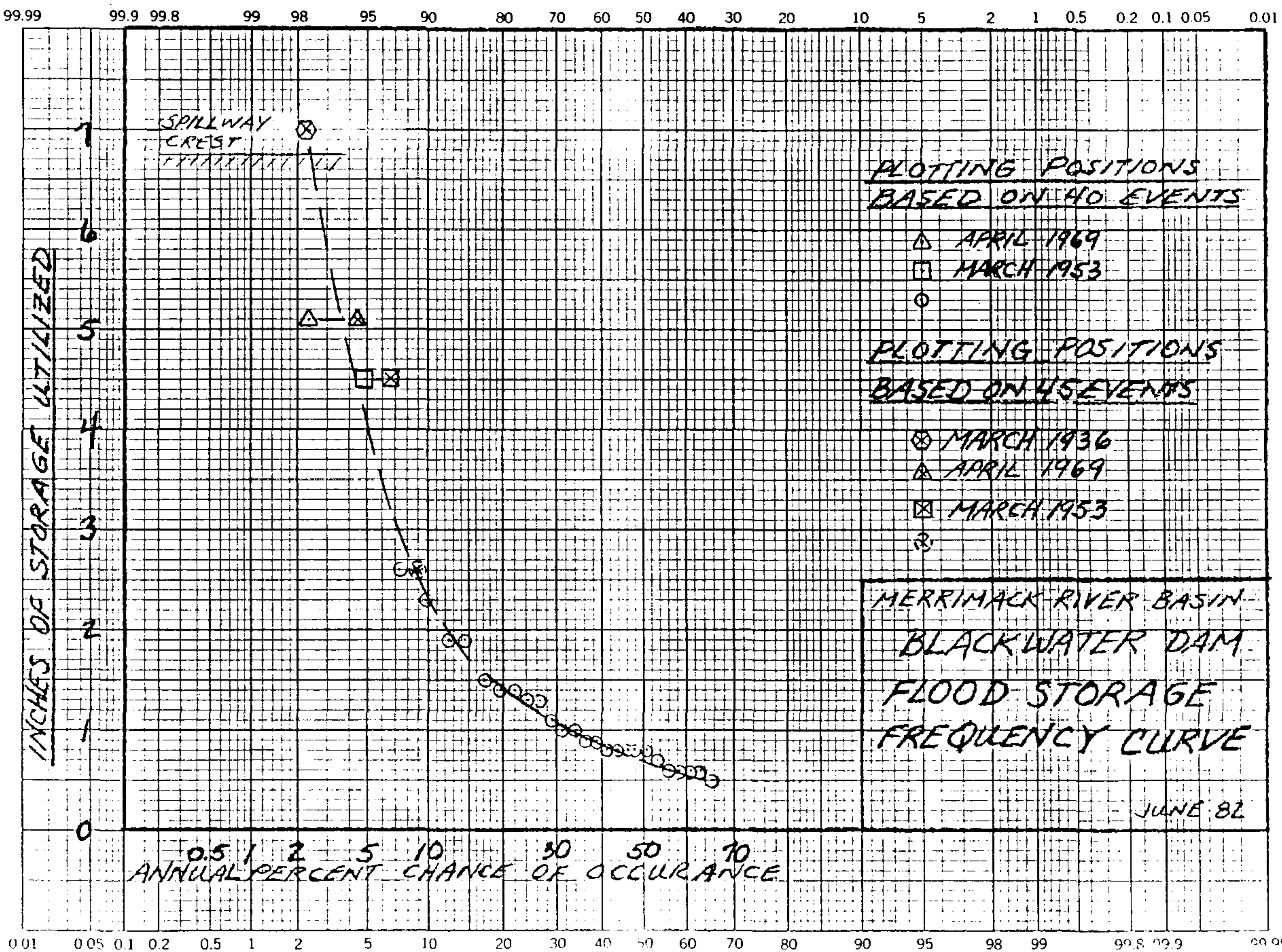

SPILLWAY CREST
INCHES OF STORAGE UTILIZED
0
1
2
3
4
5
6
7
PLOTTING POSITIONS BASED ON 40 EVENTS
APRIL 1969
MARCH 1953
PLOTTING POSITIONS BASED ON 45 EVENTS
MARCH 1936
APRIL 1969
MARCH 1953
MERRIMACK RIVER BASIN
BLACKWATER DAM
FLOOD STORAGE FREQUENCY CURVE
JUNE 82
0.5
1
2
5
10
30
50
70
ANNUAL PERCENT CHANCE OF OCCURANCE
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01

PLATE 6

Blackwater Dam Hydropower
Preliminary Feasibility Investigation

APPENDIX C

GEOTECHNICAL INVESTIGATION

Department of the Army
New England Division, Corps of Engineers
Waltham, Massachusetts

July 1986

APPENDIX C

BLACKWATER DAM HYDROPOWER STUDY
GEOTECHNICAL INVESTIGATION

TOPOGRAPHY

The project is located in the Central Highlands section of the New England region. The local topography is characterized by elongated north-northeast trending hills under 1,000 feet NGVD in elevation. Elevations increase markedly to the northwest where Mt. Kearsage rises to almost 3,000 feet. About six miles to the east of the site is the Merrimac River at about 250 feet in elevation. The project is at the upstream end of a narrow bedrock gorge more than 20 feet deep and is immediately downstream of an old glacial lake flat. Adjoining the rock gorge on the west is a broader, but shallower bedrock valley which, prior to the construction of the dam, conducted flood discharges from the main river above the dam site.

GEOLOGY

The local bedrock is a gneiss of the Littleton Formation into which a granite (Kinsman Quartz Monzonite) is intruded. The granite is the rock that comprises the dam foundation and the gorge just downstream of the dam. The gneiss generally forms the lower and flatter areas of the reservoir and the terrain downstream of the highway bridge which spans the east end of the gorge. For the most part, the granite bedrock is highly fractured while the gneiss tends to be more massive. The gorge itself is possibly fault controlled. The rock underlying the entire length of the dam was grouted to retard possible leakage from the anticipated conservation pool. Overburden in the area is seldom over 15 feet thick.

SEISMICITY

Blackwater Dam is located within seismic zone 2 as defined by the map contained in ER 1110-2-1806. This regulation requires that a seismic coefficient of 0.05g be used in determining the sliding and overturning stability of all concrete structures.

FOUNDATION INVESTIGATION

No new subsurface investigations were performed for this study. The foundation conditions for the proposed powerhouses, penstocks, and weir structures were inferred from the original explorations performed for Blackwater Dam. Borings designated D1 through D5, D11, D13, and D29 are located in the vicinity of the proposed structures. A plan showing the locations of the borings and graphic logs of the borings are shown on Plates 2 and 3, respectively.

FOUNDATION CONDITIONS

Five options, designated Alternatives 1 through 5, are currently under consideration for Blackwater Dam. Alternatives 1 and 2 involve the installation of a submersible/turbine(s) in a new concrete weir structure attached to the inlets of two of the flood control outlets. Alternative 3 involves the construction of a powerhouse at the downstream toe of the dam in the stream channel and tied into one of the flood control outlets. Alternatives 4 and 5 involve the construction of a 7 foot diameter penstock extending from the existing 16 foot diameter penstock opening through the dam to a new powerhouse on the right bank of the Blackwater River downstream of the dam. The various powerhouses and structures proposed for the five alternatives will be founded on bedrock. Some drilling and blasting will be required.

Several penstocks alignments are under consideration for Alternatives 4 and 5, which either follow the right bank of the river to a powerhouse located approximately 1,200 feet downstream, or take an inland route to a powerhouse located approximately 3,000 feet downstream. Overburden cover for the proposed right bank alignments ranges from 0 to 5 feet thick, and consists primarily of sand and gravelly sand with cobbles. Overburden cover along the proposed inland alignment ranges from 3 to 10 feet thick and consists of silty and gravelly sands with cobbles and boulders in the deeper zones near the bedrock surface.

IMPACTS ON EXISTING PROJECTS

Impacts on the geotechnical features of the dam due to the addition of hydropower will be minimal since all of the alternatives under consideration involve the use of either the existing flood control outlets or the existing 16-foot diameter penstock, all of which pass through the concrete portion of the dam. Seepage through the embankment will increase slightly due to the establishment of a permanent hydropower pool, but existing seepage control features of the dam are considered adequate to control the increased flow. Prior to the establishment of a permanent hydropower pool, piezometers should be installed in the embankment and foundation to monitor the phreatic surface in the dam.

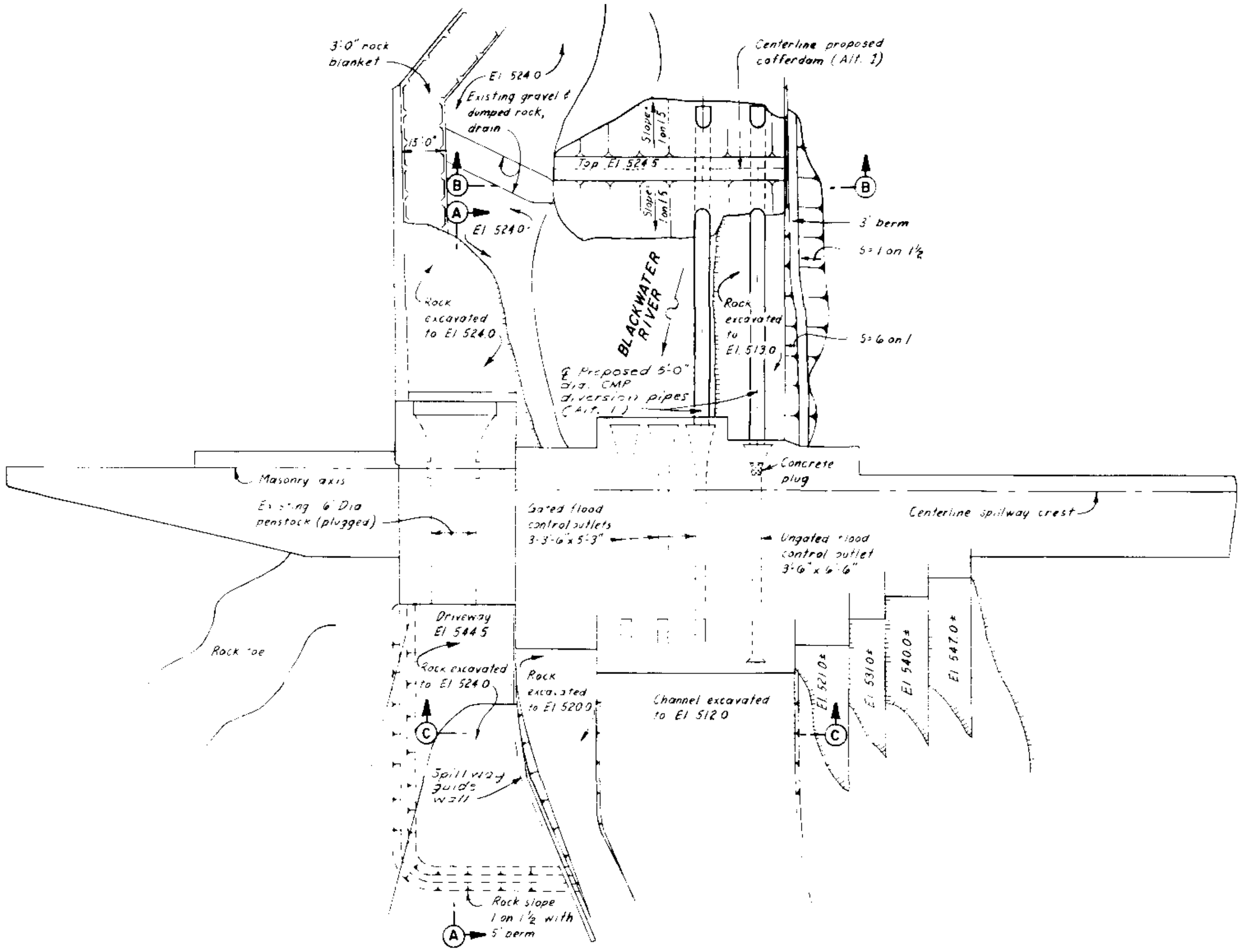
The stone protection on the upstream slope of the dam is in good condition, and should not be adversely affected by the flucuating hydropower pool. Some minor sloughing of the reservoir slopes may occur due to the hydropower operation, but should stabilize itself within the first few years. Erosion of the channel downstream of the dam is not expected to increase due to the hydropower releases.

Blasting will be required immediately downstream of the dam for the penstock for Alternative 3 and for the powerhouse for Alternative 3. Vibrations due to the blasting should be monitored and controlled to prevent damage to the existing structures.

CONTROL AND DIVERSION OF WATER

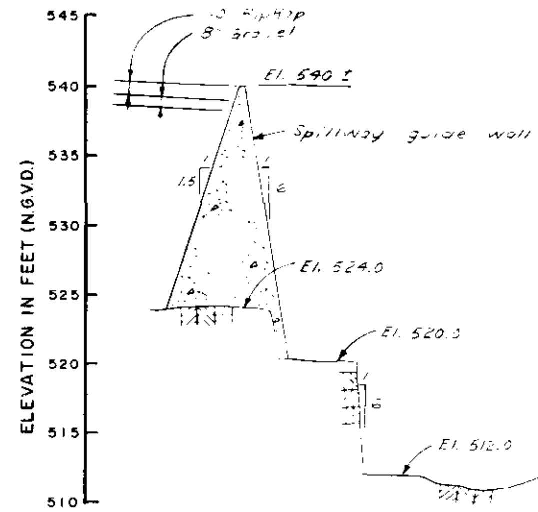
During construction of the proposed concrete weir structure for the submersible installation (Alternative 1 and 2), the site must be dewatered. The proposed diversion scheme involves the construction of a gravel fill cofferdam across the streambed to Elevation 523 feet NGVD. The cofferdam will be made impervious by placing an impervious membrane on its upstream slope. The slopes and crest of the cofferdam will be protected with an 18-inch layer of stone protection. Normal stream flows will be diverted through two 5-foot diameter corrugated metal pipes which will pass through the cofferdam and tie into two of the existing flood control conduits. One of the pipes will tie into the ungated outlet which was plugged in 1951, and the other will tie into the adjacent gated outlet. The two pipes will be supported throughout their length by a mound of gravel fill. A plan of the proposed cofferdam and diversion pipes are shown on Plate 1. Typical cross section are shown on Plate 4.

Alternative 3 involves the construction of a powerhouse excavated into the streambed at the downstream toe of the dam. A two-foot to three-foot high sandbag cofferdam will be sufficient to divert water around the construction site. Alternatives 4 and 5 involve the construction of a powerhouse on the right bank of the Blackwater River at some point just downstream of the dam. In order to dewater the construction site, a cofferdam constructed to the elevation of the streambank will be required. The cofferdam will tie into the existing streambank immediately upstream and downstream of the site. The height of the cofferdam will vary from 5 feet to 10 feet above the streambed depending on site conditions at the selected powerhouse location. The cofferdam will be constructed of random fill from the required excavations for the project with an impervious membrane and stone protection on the riverside slope. A typical section of the proposed cofferdam is shown on Plate 4.



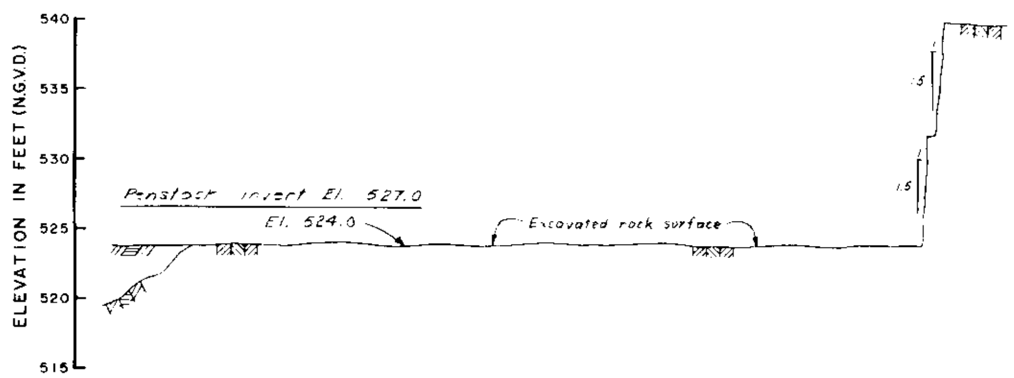
PLAN

SCALE: 1" = 20'



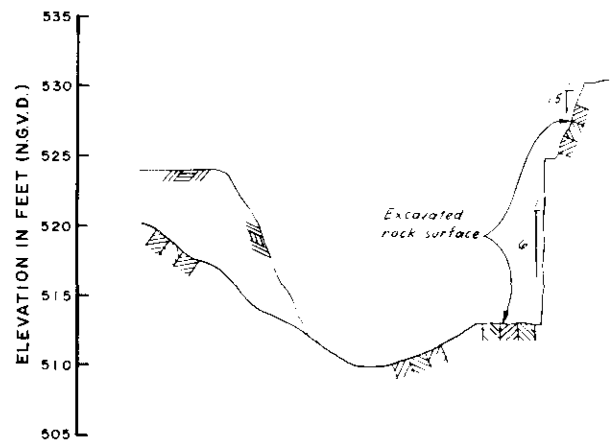
SECTION C-C

SCALE HORIZ 1" = 20' VERT 1" = 5'



SECTION A-A

SCALE: HORIZ. 1" = 20' VERT. 1" = 5'



SECTION B-B

SCALE: HORIZ 1" = 20' VERT 1" = 5'

NOTES:

1. See Plate 4 for cofferdam sections.

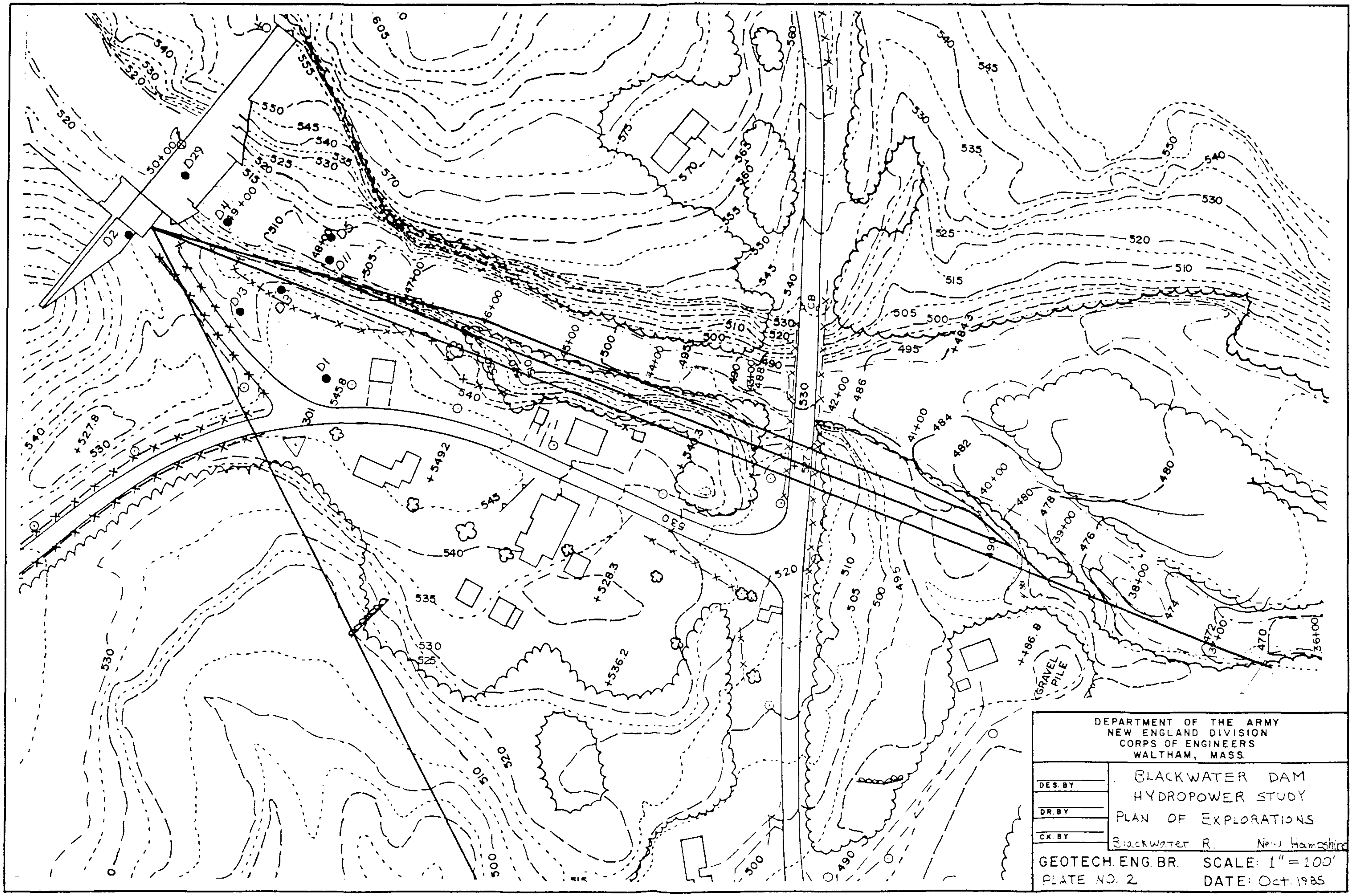
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WATER RESOURCES DEVELOPMENT PROJECT
MERRIMACK RIVER BASIN

BLACKWATER DAM
HYDROPOWER STUDY
PLAN, ROCK LINES AND DIVERSION PLAN FOR ALTERNATIVE I
BLACKWATER RIVER NEW HAMPSHIRE

DES. BY: R.D. & T.B.
DR. BY: S.K.
CK. BY: Y.Y.

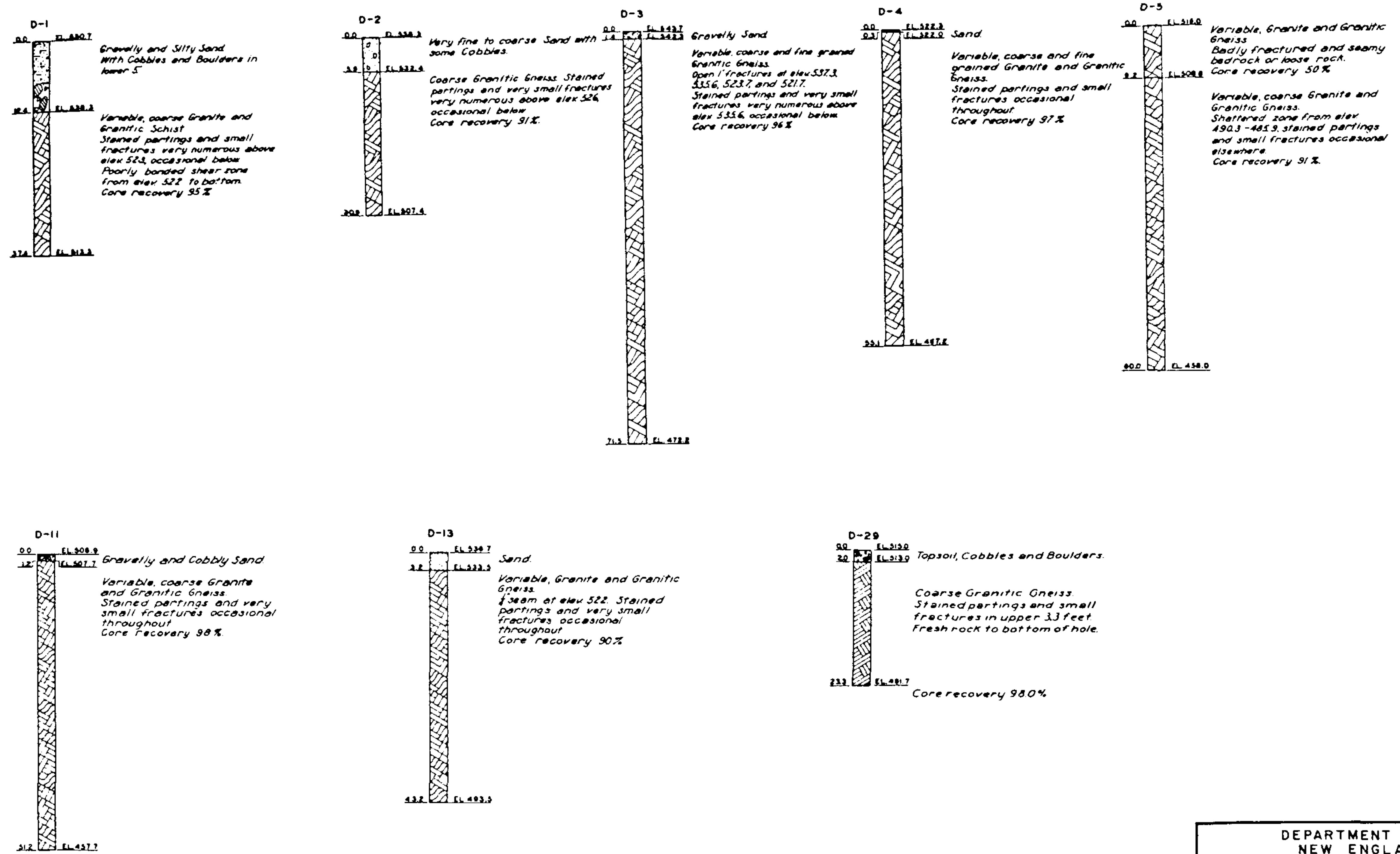
GEOTECH. ENG. BR.
PLATE 1
SCALE: AS SHOWN
DATE: OCT. 1985



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY	BLACKWATER DAM
DR. BY	HYDROPOWER STUDY
CK. BY	PLAN OF EXPLORATIONS
	Blackwater R. New Hampshire

GEOTECH. ENG. BR. SCALE: 1" = 100'
PLATE NO. 2 DATE: Oct. 1985

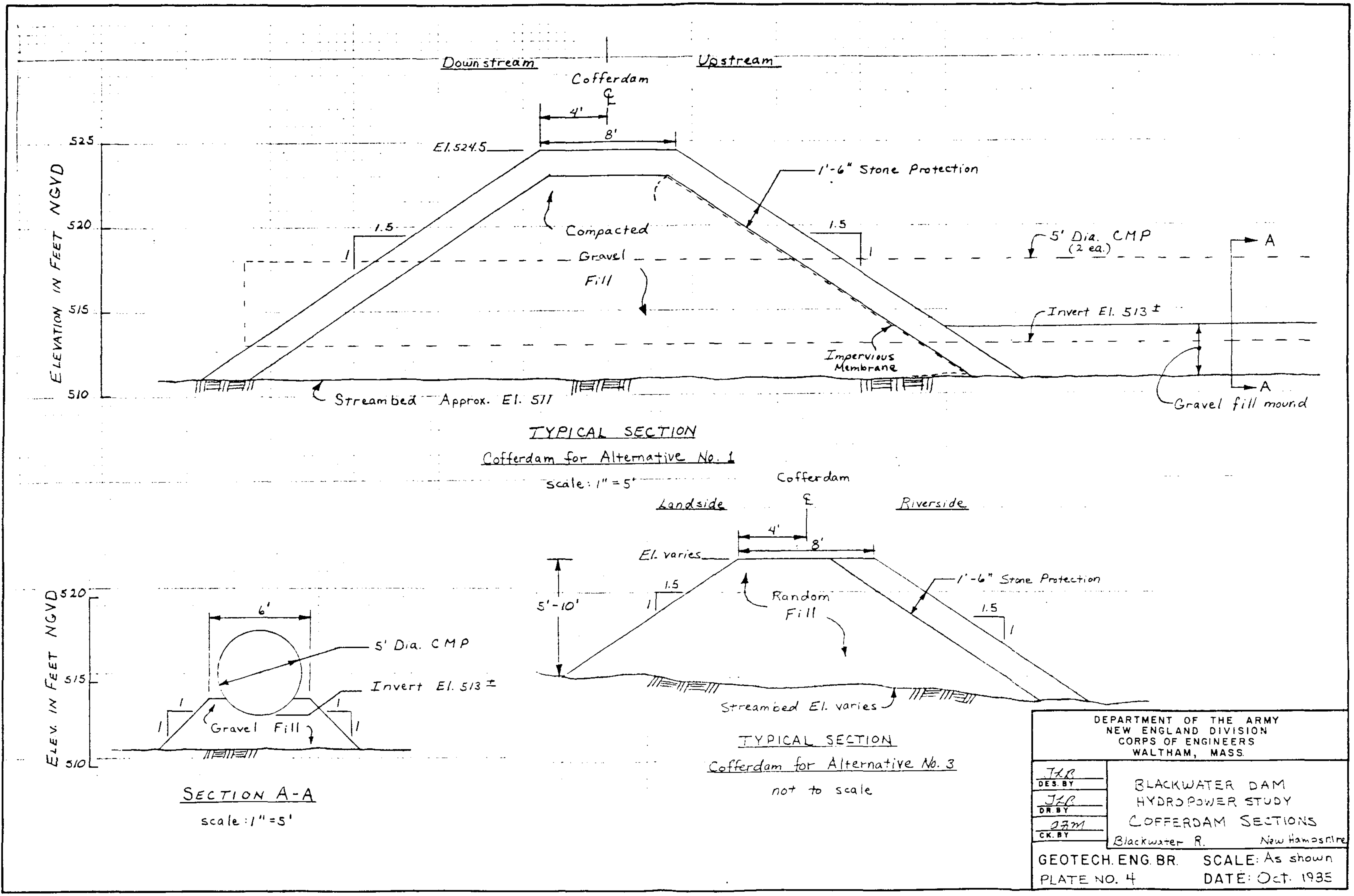


DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY
DR. BY
CK. BY

BLACKWATER DAM
HYDROPOWER STUDY
RECORD OF EXPLORATIONS
Blackwater R. New Hampshire

GEOTECH. ENG. BR. SCALE: NONE
PLATE NO. 3 DATE: SEPT 1985


Downstream
Upstream
Cofferdam
4'
8'
El. 524.5
525
520
515
510
ELEVATION IN FEET NGVD
1'-6" Stone Protection
Compacted
Gravel
Fill
1.5
1
1.5
1
5' Dia. CMP
(2 ea.)
A
Invert El. 513 ±
Impervious
Membrane
Streambed Approx. El. 511
Gravel fill mound
A
TYPICAL SECTION
Cofferdam for Alternative No. 1
scale: 1" = 5'
Cofferdam
Landside
Riverside
4'
8'
El. varies
5'-10'
1.5
1
Random
Fill
1'-6" Stone Protection
1.5
1
Streambed El. varies
TYPICAL SECTION
Cofferdam for Alternative No. 3
not to scale
ELEV. IN FEET NGVD
520
515
510
6'
5' Dia. CMP
Invert El. 513 ±
1
1
1
1
Gravel Fill
SECTION A-A
scale: 1" = 5'
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
JLR
DES. BY
JLR
DR. BY
JFM
CK. BY
BLACKWATER DAM
HYDROPOWER STUDY
COFFERDAM SECTIONS
Blackwater R.
New Hampshire
GEOTECH. ENG. BR.
SCALE: As shown
PLATE NO. 4
DATE: Oct. 1985